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INDIANA
DEPARTMENT OF TRANSPORTATION

JOINT HIGHWAY RESEARCH PROJECT

FHWA/IN/JHRP-91/12

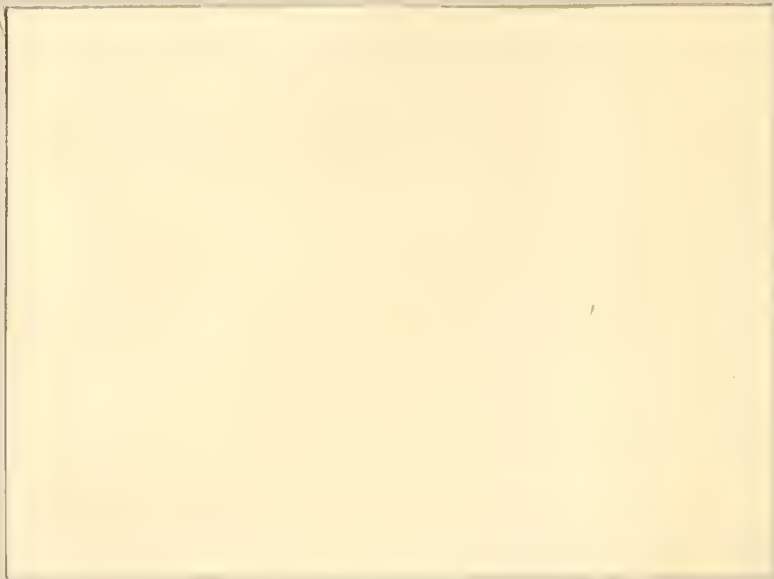
Final Report

MULTIOBJECTIVE DESIGN OF SERVICE
ROUTE

Jeff R. Wright
Jin-Yuan Wang



PURDUE UNIVERSITY



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Final Report
MULTIOBJECTIVE DESIGN OF SERVICE ROUTES

TO: V. P. Drnevich, Director
Joint Highway Research Project

FROM: Jeff R. Wright, Research Engineer 
Joint Highway Research Project

DATE: January 13, 1993

RE: Multiobjective Design of Service Routes
Project Number C-36-67CC
File Number 9-11-29

Attached is the Final Report of JHRP C-36-67CC entitled "Multiobjective Design of Service Routes." This report presents the results of this study including the description of a Decision Support System for public sector service route design. This report was prepared and the research work was conducted by Jeff R. Wright and Jin-Yuan Wang.

The report is forwarded for review, comment, and acceptance by the INDOT and FHWA as fulfillment of the objectives of the research.

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Final Report

MULTIOBJECTIVE DESIGN OF SERVICE ROUTES

by

Jeff R. Wright
Professor of Civil Engineering
and
Research Engineer

and

Jin-Yuan Wang
Graduate Student

Joint Highway Research Project
Project No. C-36-67CC
File No. 9-11-29

Prepared as part of an investigation conducted by Joint Highway
Research Project, Engineering Experiment Station
Purdue University

In cooperation with the Indiana Department of Highways
and the U.S. Department of Transportation

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration.
This report does not constitute a standard, specification, or regulation.

Purdue University
West Lafayette, IN 47907

January 13, 1993

THEORY

THEORY OF THE EARTH AND ITS HISTORY

1. THE EARTH

2. THE EARTH'S HISTORY

3. THE EARTH'S HISTORY

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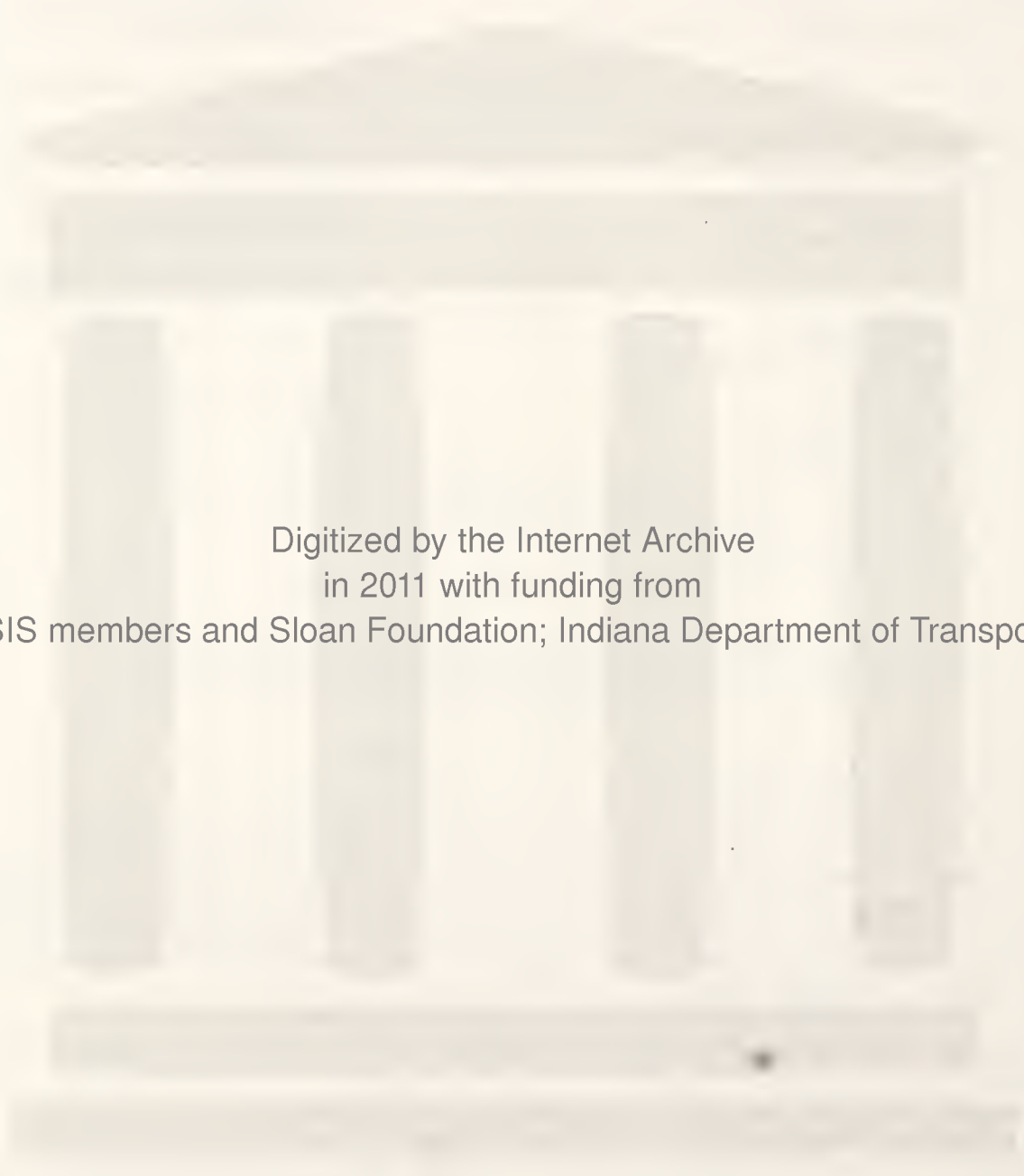
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16. Abstract The purpose of this research has been the design of a computer-based decision support system for use in the design of service routes on the Indiana intrastate highway system. The following work has been completed for this purpose: 1) Acquisition of a 1:100,000 scale DLG data representation of the entire state transportation network. 2) Reclassification of those data with the aid of a computer-based interactive data filter and participation by DOT maintenance personnel from 6 districts. 3) Development of several route design algorithm components designed specifically for addressing the problem of routing snow and ice control vehicles for INDOT. 4) Design, development, and testing of a graphical user interface (GUI) to facilitate the use of these algorithms by an experienced highway engineer faced with designing service routes. 5) Training of key INDOT personnel in the use of this system. 6) Testing of this system by using it to design service routes for several sub-segments of the Indiana transportation system (under development). 7) Assisting INDOT Data Services personnel in the implementation of this design (under development). The preliminary testing results on the Carbondale unit show that significant savings can be obtained while adhering to the requirements of INDOT, and in addition, even better service may be provided.			
17. Key Words Decision support system, service route design, data classification, graphical user interface, heuristic optimization		18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161	
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Implementation Report

Multiojective Design of Service Routes

by

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October, 1991

Summary

Work has recently been completed on the design and development of a prototype system for use in snow route design and management. The results of this research fall into three separate, but related areas: 1) analysis of analytical procedures available for performing route design and analysis, 2) analysis of data availability and adaptability to support these analytical procedures, and 3) consideration of the appropriate user environment for conducting route design and analysis within the protocols presently employed by the service authority (in this instance, the Indianapolis Department of Transportation). The product of that research is a **Computer Aided System for Designing Efficient Routes (CASPER)**, having general applicability to a variety of service route design problems, and particular significance for snow and ice control route design and analysis.

This document provides a recommendation for system implementation consisting of two parallel activities: 1) the transfer of the CASPER modeling environment to the Indiana Department of Transportation (INDOT) computational environment (involving a translation of the software to a McDonnell-Douglas CAD framework), and 2) initiation of route design activities by INDOT personnel using the CASPER prototype software at Purdue University.

Rationale

CASPER is an interactive spatial modeling environment that was developed specifically for use by INDOT maintenance personnel in the design of snow and ice maintenance service routes. Specifically, the system has demonstrated a remarkable ability to solve the following problem:

Given a pre-designated partition of the service network to be serviced by multiple vehicles out of a single depot, and detailed information about service ability on that subnetwork (travel speeds as a function of service type, maneuverability at intersections, direction restrictions, etc., determine the minimum number of routes required to service the subnetwork to a pre-determined level of service, as well as the specific configuration of those routes.

However, because of the overall complexity of the route design process, it is essential that the CASPER design tool be used by individuals having a detailed understanding of the problem. Because these individuals are not likely to understand the details of the CASPER compute environment, it is equally essential that considerable effort be focused at user training and support. And this is best achieved by individuals who both understand the details of the system, and have a vested interest in the detailed evaluation of the results.

Two parallel work plans are suggested for the complete implementation of CASPER into INDOT operations, where it will be of use to INDOT not only for snow service route design, but other route dependant activities such as crack sealing, striping, and weed control:

1. **Software Implementation:** Transfer of the CASPER routines to the GIS environment of INDOT. This requires the "re-packaging" of the CASPER routines using the McDonnell Douglas GIS software that has been adopted by INDOT Data Services, and will require DPMC approval. This activity would be conducted by INDOT Data Services personnel, with assistance as needed by the principal investigator. The result of this activity would 1) function in a manner identical to the CASPER prototype, 2) look and feel similar to the CASPER prototype, and 3) benefit from other data management and maintenance activities currently planned for the INDOT GIS system by Data Services.
2. **Route Design Implementation:** The use of the CASPER prototype system by INDOT field personnel, and at Purdue University for the design of service routes. This would involve the establishment of a schedule for having the appropriate individuals from each district office spend on the order of a person-week at Purdue learning how to use the system, and subsequently designing routes for their respective districts.

The only other feasible approach to implementation of the previous research would be to conduct the same tasks sequentially: first implement the CASPER software, then undertake detailed route design. Some of the more important advantages of the proposed strategy include:

1. Improved snow routes for the entire state (with the possible exception for Marion Co.) would be available for the '92-93 snow season.
2. By the time the software implementation would be completed (est. 12 person months of effort), there would be an extensive user community ready to undertake the solution of other route design problems.
3. Because the results of the use of CASPER would be part of an ongoing research activity, more attention could be paid to the details of route evaluation and verification.
4. Modifications and improvements to the CASPER model could be made rapidly and efficiently because the designer and builder of the system would be intimately involved with its use in a production environment.
5. Additional uses of CASPER could be identified through close interaction between the design team and the user community.



MULTIOBJECTIVE DESIGN OF SERVICE ROUTES

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Table Of Contents

1.0	Introduction	1
2.0	The Structure and Function of CASPER	2
2.1	The Models Sub-component	2
2.2	The Data Sub-component	3
2.3	The User Interface	5
3.0	Concluding Remarks	5
4.0	References	5
5.0	Appendix A	6

1.0 Introduction

The purpose of this research has been the design of a computer-based decision support system for use in the design of service routes on the Indiana intrastate highway system. This design is presently being tested by researchers at Purdue University School of Civil Engineering, and is being considered for implementation by the Indiana Department of Transportation (INDOT).

The central components of this effort have been:

- 1. the acquisition of a 1:100,000 scale DLG data representation of the entire state transportation network.*
- 2. the reclassification of those data with the aid of a computer-based interactive data filter, and participation by INDOT maintenance personnel from each of the six district offices.*
- 3. the development of several route design algorithm components designed specifically for addressing the problem of routing snow and ice control vehicles for INDOT (i.e. these algorithms adhere to the specific policies for level of service adopted by INDOT).*
- 4. the design, development, and testing of a graphical user interface (GUI) that will facilitate the use of these algorithms by an experienced highway engineer faced with designing service routes.*
- 5. the training of key INDOT personnel in the use of this system.*
- 6. the testing of this system by using it to design service routes for several sub-segments of the Indiana transportation system.*
- 7. the assisting of INDOT Data Services personnel in the implementation of this design.*

At this point in time, components 1-5 have been completed, component 6 is in progress, and component 7 has begun. This report does not discuss the details of these components as they have been described more fully in several quarterly progress reports and two technical publications (1,2). Instead, this report is intended to give a complete overview of the route design system and its use.

The decision support system resulting from this work has been titled **CASPER**, for Computer Aided System for Planning Efficient Routes. Like its namesake "**CASPER**: the Friendly Ghost," this **CASPER** is a bit intimidating at first; particularly for individuals not familiar with high-end computer technology. But after becoming more familiar with the system, users are able to understand that **CASPER** is not a threat, but a great help in helping to address the very complex problems associated with route design.

2.0 The Structure and Function of CASPER

As a decision support system, **CASPER** incorporates three distinct sub-components or modules: 1) a models subsystem, 2) a data subsystem, and 3) a user interface. The interested reader is directed to the papers cited at the end of this report for detailed information on the models and data subsystems; a general description of these components, and a detailed description of the user interface for **CASPER** are presented below.

2.1 The Models Sub-component

The route design philosophy driving the design of **CASPER** is that complex service vehicle routing is best accomplished by an individual having a great deal of special expertise and experience in a given domain; snow and ice control in this case. While that individual understands the details and complexities of the operation, (s)he is unable to identify good strategies for route design because the solution space is so large. For example, consider the relatively small problem of determining four roughly equal service routes of 20 miles each on a network consisting of 16 5-mile road segments. The number of different route configurations possible is approximately 9×10^{11} . If our winter maintenance expert could evaluate one of these routes each second by hand, it would take approximately 100,000,000 days to arrive at an optimal routing solution for this scenario. Then consider:

- *Routes in Indiana are generally about 40 miles in length.*
- *Routes in Indiana are generally made up of 25 road segments having an average length of more like 1.6 miles.*
- *The average number of routes per unit in Indiana is more like 9-10.*
- *There are approximately 986 snow routes in Indiana, servicing on the order of 30,000 lane miles.*

And this assumes that the basic highway network is already partitioned into sub-elements (called units) in some optimal fashion. In short, the problem of designing effective snow and ice control routes is extremely complicated; commonly accepted as the most complicated public-sector routing problem.

CASPER is properly described as a computer aided design tool for helping an expert maintenance engineer explore a more complete set of feasible routing solutions than (s)he would be able to consider by hand. Further, the system allows this individual to configure their own strategy for accomplishing route design. That is, two individual route design experts might use **CASPER** in very different ways, depending on their own preferences and experiences. For example, one individual might wish to start the route evaluation/design process by focusing on existing route structure, and proceed to make improvements in an iterative fashion. Another individual might wish to begin with a completely new set of routes. Or one maintenance engineer might view the minimization of deadhead miles during the operation to be the most important consideration in route design, while another might be less concerned with total deadhead miles than with the homogeneity of route types (There are three types of snow routes in Indiana based on average daily traffic (ADTs) counts. It is generally more desirable to have any single snow route consist of only one class of roadway.). Using **CASPER**, the individual charged with evaluating/designing routes can specify their own approach based on their preferences. From this perspective, **CASPER** is most properly viewed as a CAD (Computer Aided Design) system for designing service routes.

2.2 The Data Sub-component

For the application of vehicle routing over the state highway network, a complete description of the network is required. This description must include all major intersections in each district, adjacency information, which indicates which intersections are joined directly by roads, and the lengths of each of these roads. Planning for snow and ice control requires additional information, such as the width in lanes of every roadway,

and more complete descriptions of intersections, including features such as turn lanes or traffic control devices. Currently the most effective means of assembling such data has been to produce a network by reading the information from a highway map, and then add additional arcs to the graph to account for multiple lanes. On a statewide basis, this process could prove incredibly exhausting, and the accuracy of the resulting maps could be less than desired.

A major effort of this research has been to explore available digital map data sources, and to find the best methods to convert this data to a usable network representation. One class of geographic data considered is a raster, or grid, format. Data gathered by aerial or satellite photography is in this form. A raster format is impractical for a network application due to the large amount of processing required to extract the roadway information from the data grid. Also, to obtain accurate distances along roads, the sampling size of the raster format must be fairly small, or the errors in calculation would be multiplied many times over.

The most promising format for this application is a vector format. Roadways are represented as polylines, that is, a set of short segments connecting two intersections. Many basic functions would be simplified, especially those of finding adjacent intersections and road lengths. The source for vector data thus far has been the U.S. Geological Survey Digital Line Graph (DLG) format. Roadway information is available for the state of Indiana at 1:100000 scale.

As part of the National Mapping Program, the Geological Survey is creating this database by digitization of existing 1:24,000 scale archival maps. Current estimates from the agency indicate that the coverage of the United States in 1:24,000 scale digital maps is only two percent complete for hydrography and transportation information. However, to complete a database for the 1990 decennial census, the Survey has produced a set of digital form, 1:100,000 scale maps for transportation and hydrographic information. Because this research project was primarily concerned with representation of the highway network, the available 1:100,000 scale DLG format data is adequate. The critical information for use of these data in a geographic information system are the availability and expense of the distributed data, its logical format, and its accuracy.

The data for the 1:100,000 scale DLG map is partitioned into the categories of hydrography and transportation, which includes roads, railways, pipelines, transmission lines, and airports. The digital information corresponding to these layers have been available from the Geological Survey since late 1986. Boundary information, which would include digitized limits of cities, counties, and states is only partially complete. The transportation maps representing a thirty minute square area in north central Indiana, and the boundary information for three quarters of this area, were purchased for under five hundred dollars.

The DLG data format is a vector representation of the environment. Map information is distributed by the National Cartographic Information Center of the Geological Survey in two formats: standard and optional. The primary difference in the formats is the internal measurement units used. In the standard format, all coordinates are given in pure integer values which can be mathematically transformed into geographic coordinates. The Survey recommends use of the optional format distribution of the data, in which all coordinates are recorded in Universal Transverse Mercator (UTM). The optional format also includes a more complete set of linkages between node, line, and area information.

The Geological Survey does not quantify the accuracy of the produced DLG maps. Because the maps are produced from original archived maps, few allowances can be made for changes to the map area since last revision of the source data. Future goals of the National Mapping Project are to standardize all published maps, and to implement a five to ten year cyclic inspection process. Most necessary changes to the map database would be made after the entire national database is digitized. Critical changes to the map database may be made by the Geological Survey upon special request. Alternatively, the data user could attempt to modify his personal copy of the map data. The Survey does, however, state certain efforts made to insure the digitized map correctly represents the source map.

The DLG data users guide states that manually digitized source maps have a resolution of 0.001 inch, with an accuracy of no less than 0.005 inch. If the source map was digitized automatically, a resolution of 0.0013 inch. The guide further states that the digitized data are plotted and compared to the source material. The plots are checked for positional accuracy and completeness of the graph. Attribute information for the map is entered manually using the original source map as a reference, and then checked by software to guarantee only valid codes were entered. This process does not, and could not easily check the entered attributes to verify that they provide a necessary and sufficient description of the line. Topological fidelity, or planarity, of the data is verified by software. This guarantees that no lines cross except at nodes, and that any line entering a node ends at that node. Edge matching of positions and attributes is said to be performed whenever the adjacent cells are available in the database. Experimental experience with this data will show that this edge matching procedure may not be sufficient.

The use of these data for route design and analysis is hindered by two distinct factors. First, the DLG data set includes considerably more data than are needed for route design.

Second the classifications used by USGS may not be satisfactory for a given route design problem. For example, USGS does not classify intersection nodes as being inappropriate for maneuvering a snow removal vehicle through a U-turn. Existing map representations of the highway network could be used as a data source for optimization, although the complexity of this data could prove difficult in the definition of solution methods. Only with intelligent and efficient filtering, these data are a useful resource in many fields of operations research.

The interactive DLG-3 data filter used in this research consists of three separate functions: 1) input of the original DLG-3 data files, 2) interactive reclassification of road segment and node (intersection) objects, and 3) output of reclassified data files in DLG-3 format. These functions are contained within **CASPER**, and have been used to develop a network vector database for the entire State of Indiana. The operation of this process is presented in the sample user session appended to this report.

2.3 The User Interface

The graphical user interface (GUI) developed for **CASPER** is presented as an appendix to this report and in the form of a set of annotated computer screen displays showing what the user would see as (s)he interacts with the system in designing service routes. This interface was developed using the OSF/MOTIF development environment under the X Windows system.

3.0 Concluding Remarks

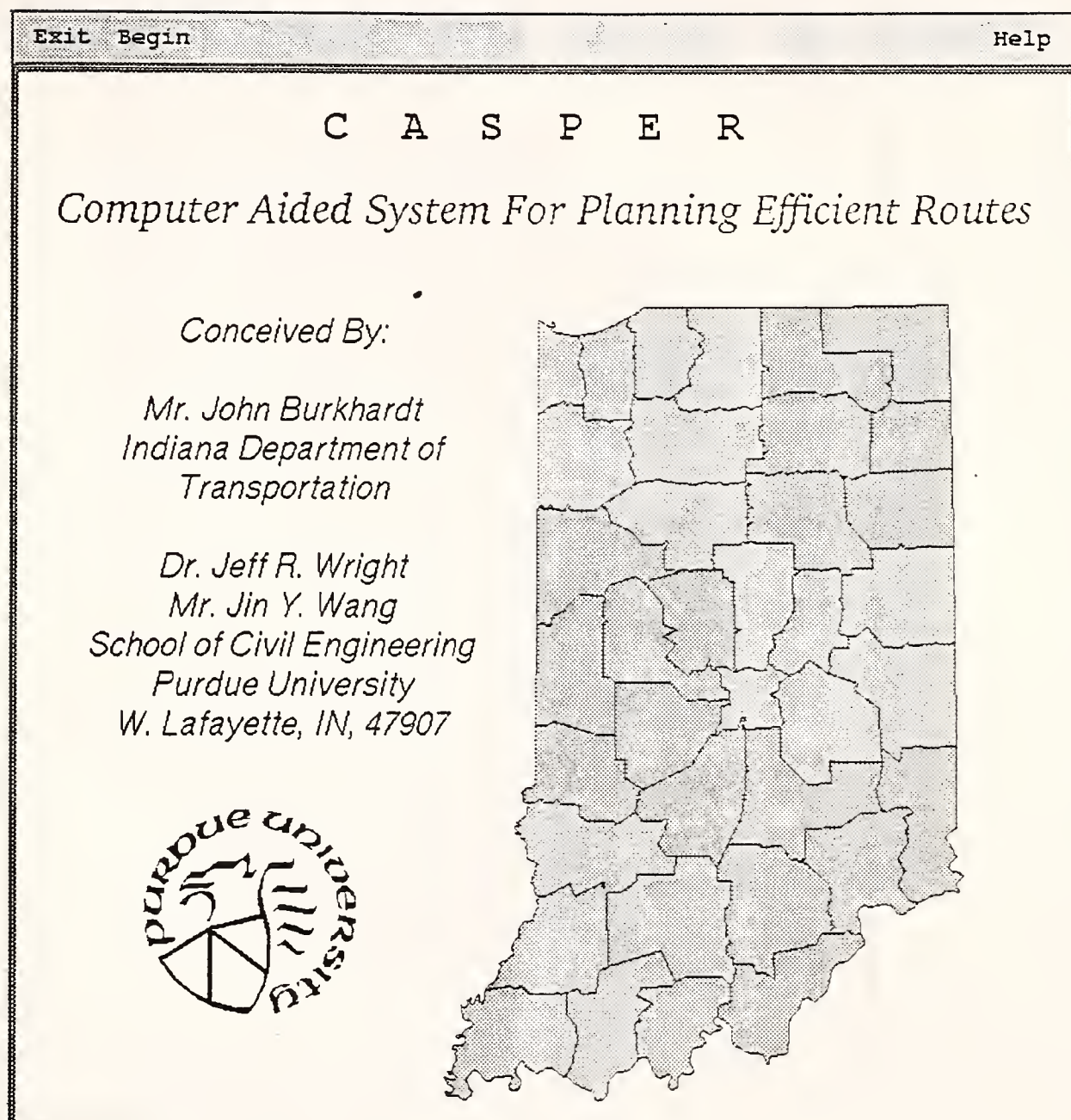
The **CASPER** service route design prototype represents a unique approach to the design of transportation service routes; one that places the maintenance engineer in the role of expert, and the computer support system in the role of technical assistant or accountant. The result is a system that is both powerful and flexible, and that shows great promise in developing improved service routes on one hand, and possibly reducing the number of service routes necessary to achieve an acceptable level of service on the other. The final version of this report (expected to be available in January, 1992) will present the results from testing CASPER throughout the state.

4.0 References

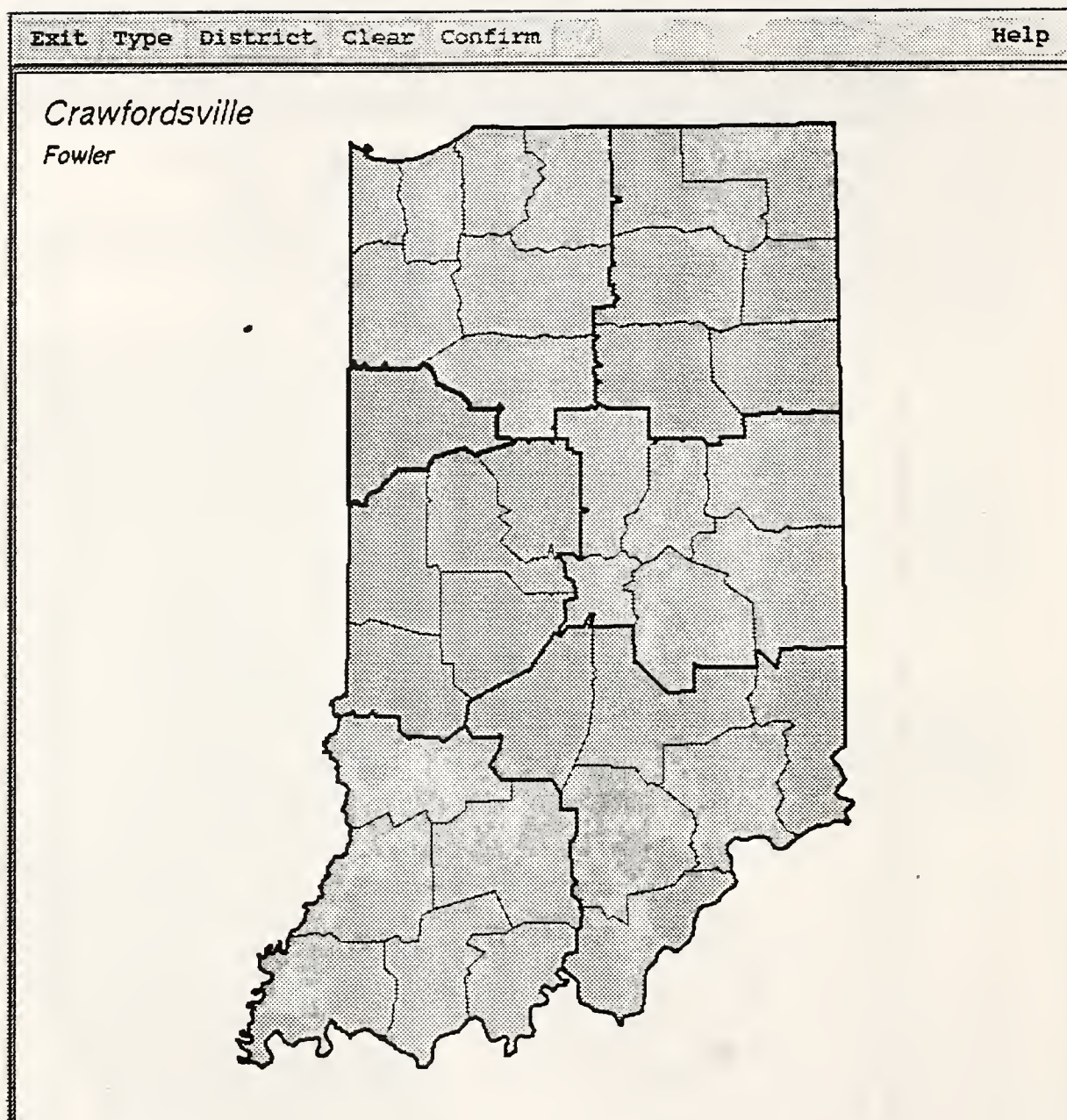
1. Haslam, Edward, and Wright, Jeff R., "Application of Routing Technologies to Rural Snow and Ice Control," *Transportation Research Record* (forthcoming).
2. Wang, Jin-Yuan, and Wright, Jeff R., "Integrating GIS and CAD for Transportation Database Development," *Transportation Research Record* (forthcoming).

5.0 Appendix A

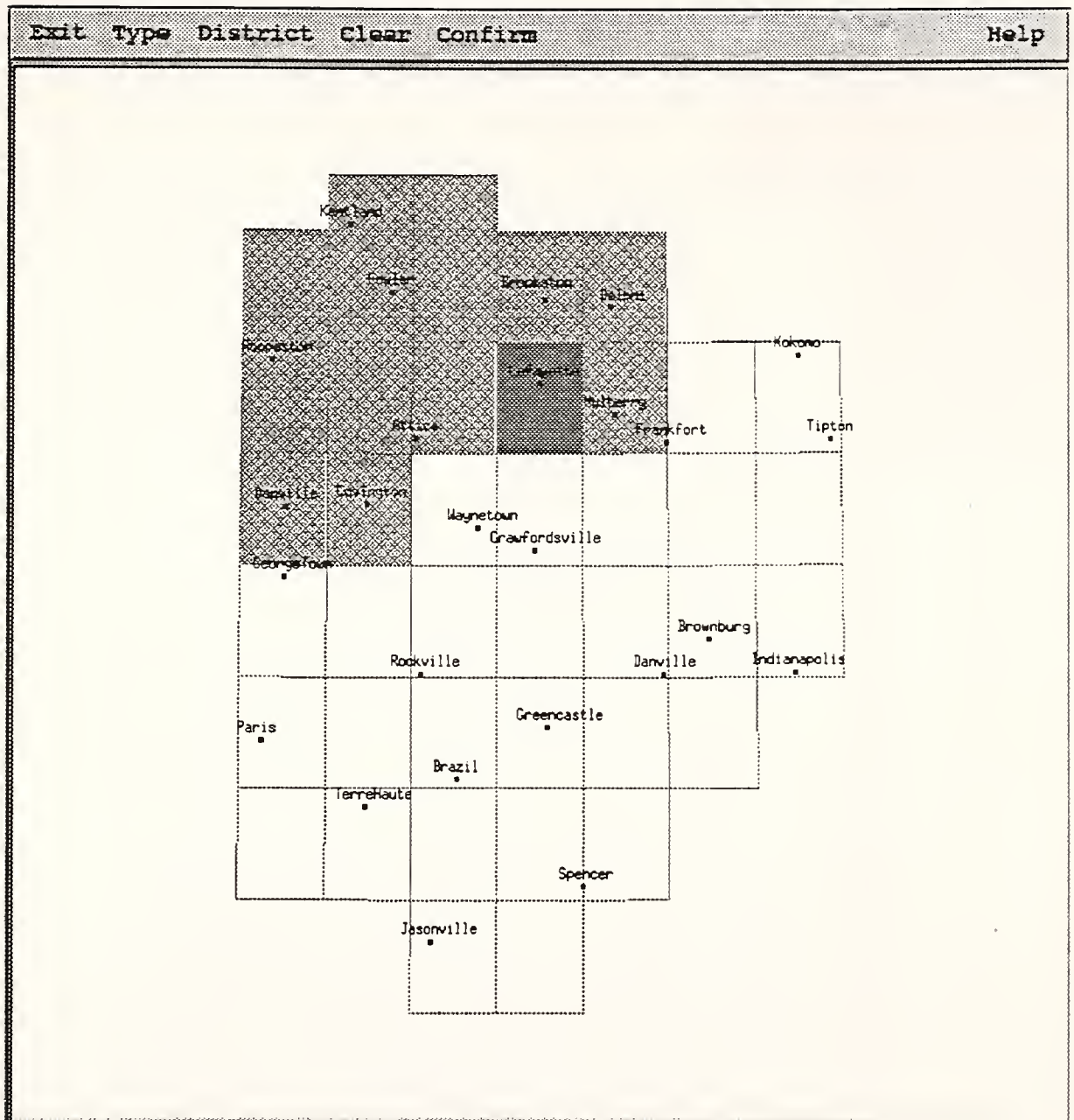
The following sequence of annotated figures presents a detailed look at the use of **CASPER** from the standpoint of an individual experienced in the winter snow and ice control operation in Indiana, but not necessarily in the use of interactive CAD technology. All data and sample route design operations are real.



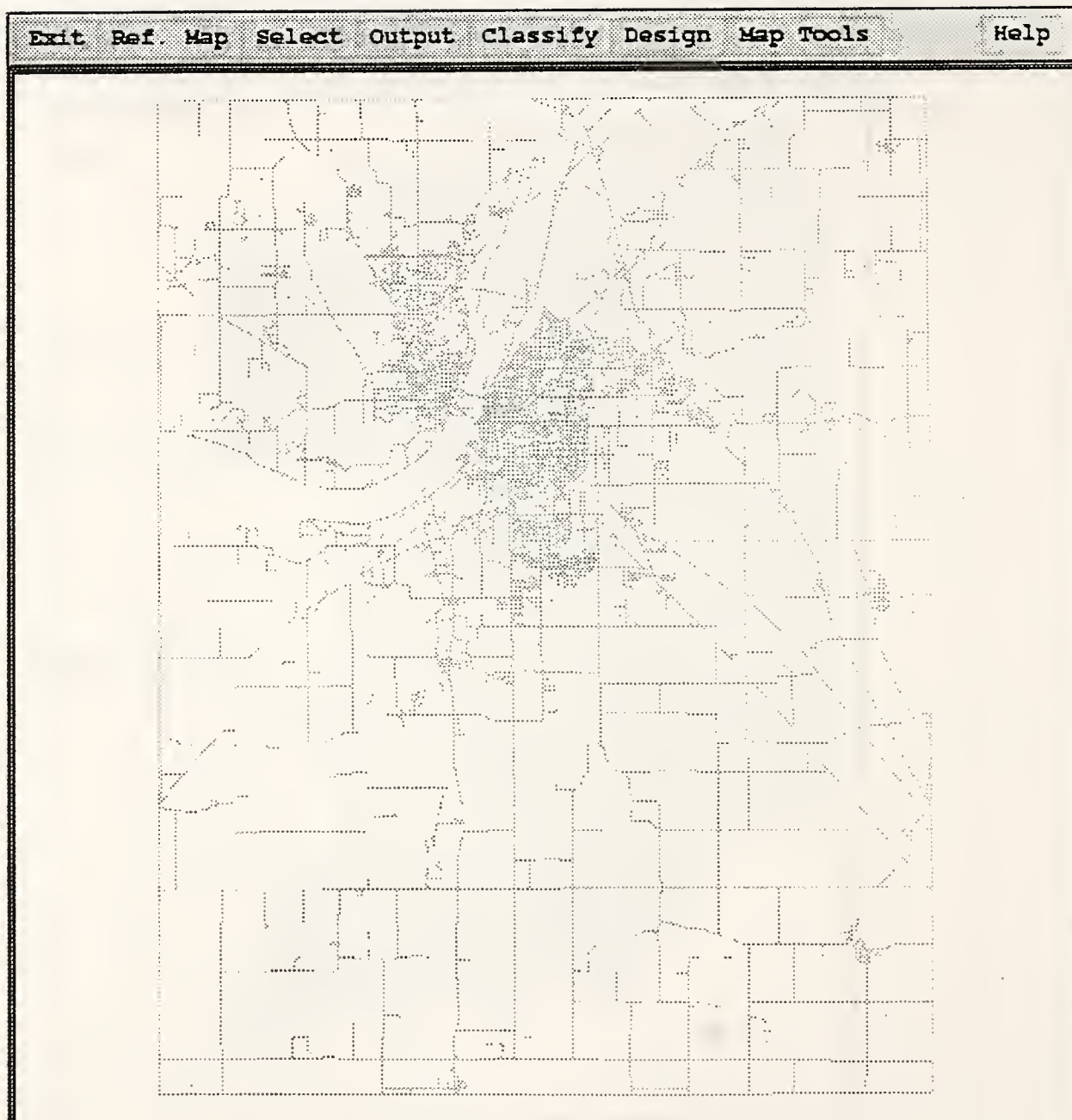
This figure shows the initial screen display of CASPER. A master menu bar resides at the top of the screen. The user can move the mouse pointer to any desired menu item, click the mouse button, and invoke that particular function. Clicking on the "Begin" menu item will start the interaction between user and CASPER.



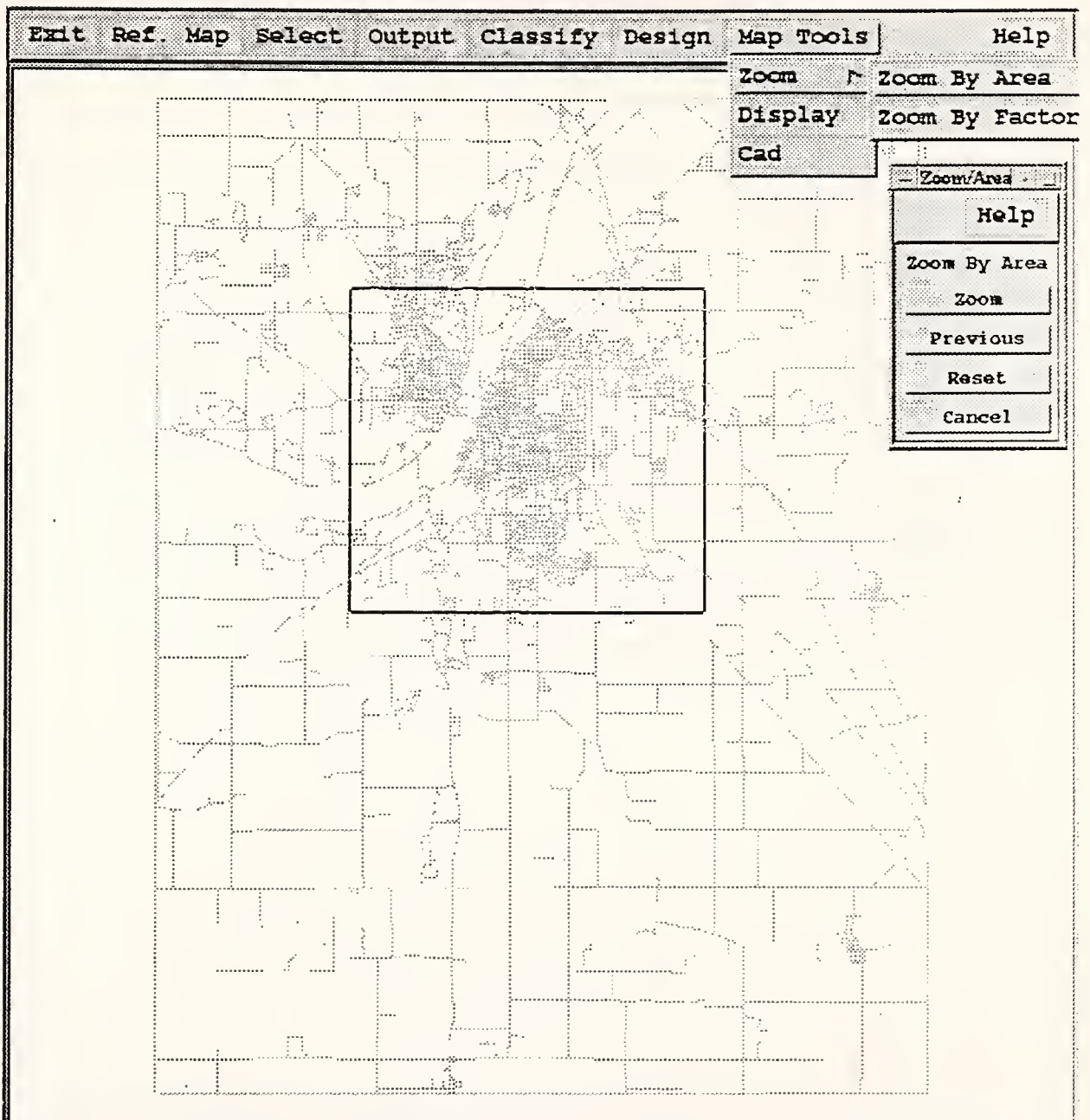
This figure demonstrates how the user can select the desired (target) area from CASPER's database. The user can move the mouse pointer to any desired district/subdistrict with the visual impact of highlighting the subdistrict that contains this pointer and displaying the names of the corresponding district and subdistrict. Confirmation of this area selection is done by clicking mouse button while the pointer is within that particular area.



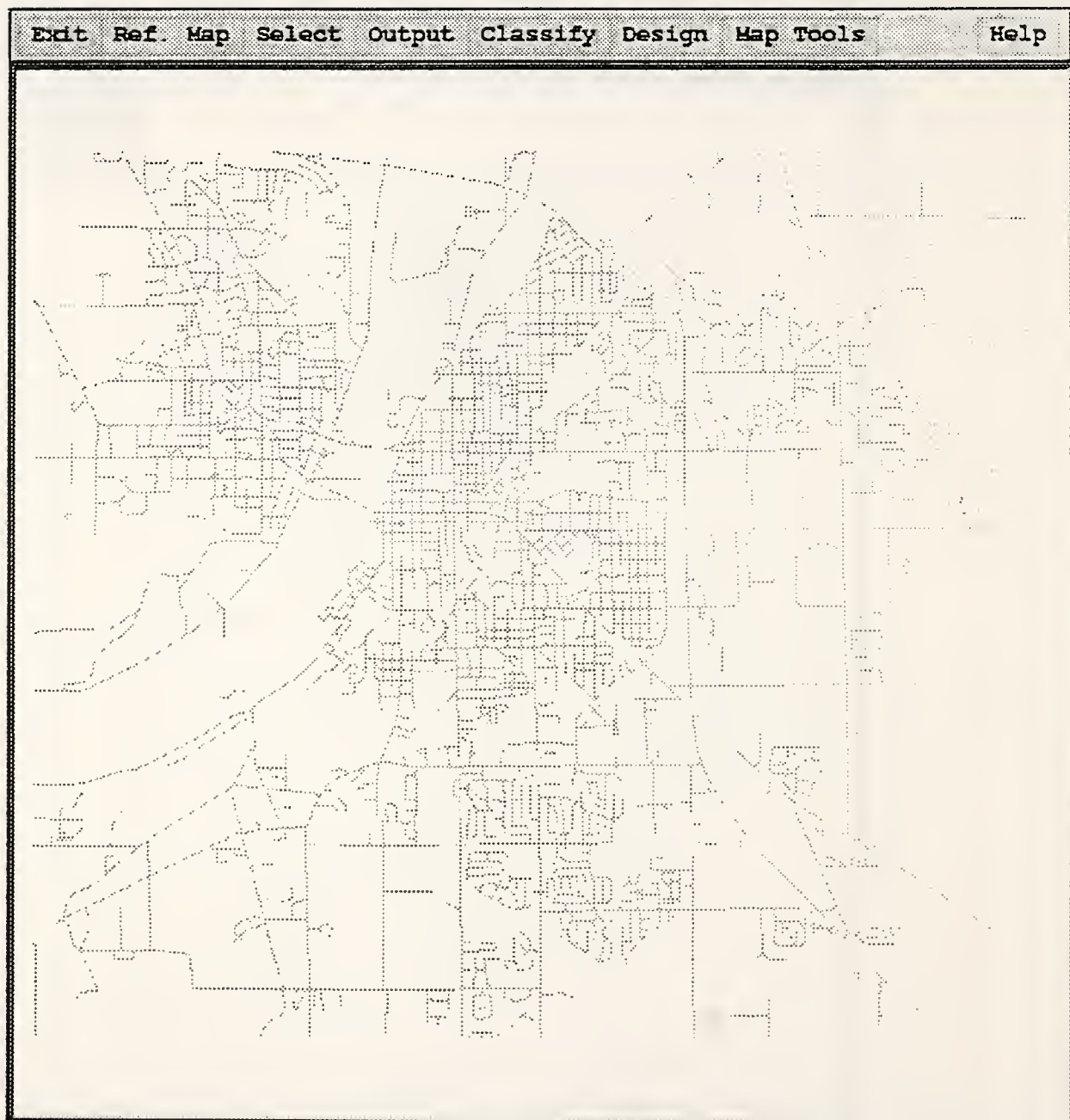
This figure shows the relationships between USGS DLG 1:100,000 data and the selected subdistrict. The rectangles represent the DLG files within this selected district. The rectangles with shadow background represent the files within the selected subdistrict. The name of major cities/towns are drawn for user's reference. The user can select any portion of this area by clicking the mouse pointer within the desired rectangle. The selected files will be highlighted with a darker color. The user may select as many files as (s)he wants from this screen and CASPER will merge all of the selected files into one.



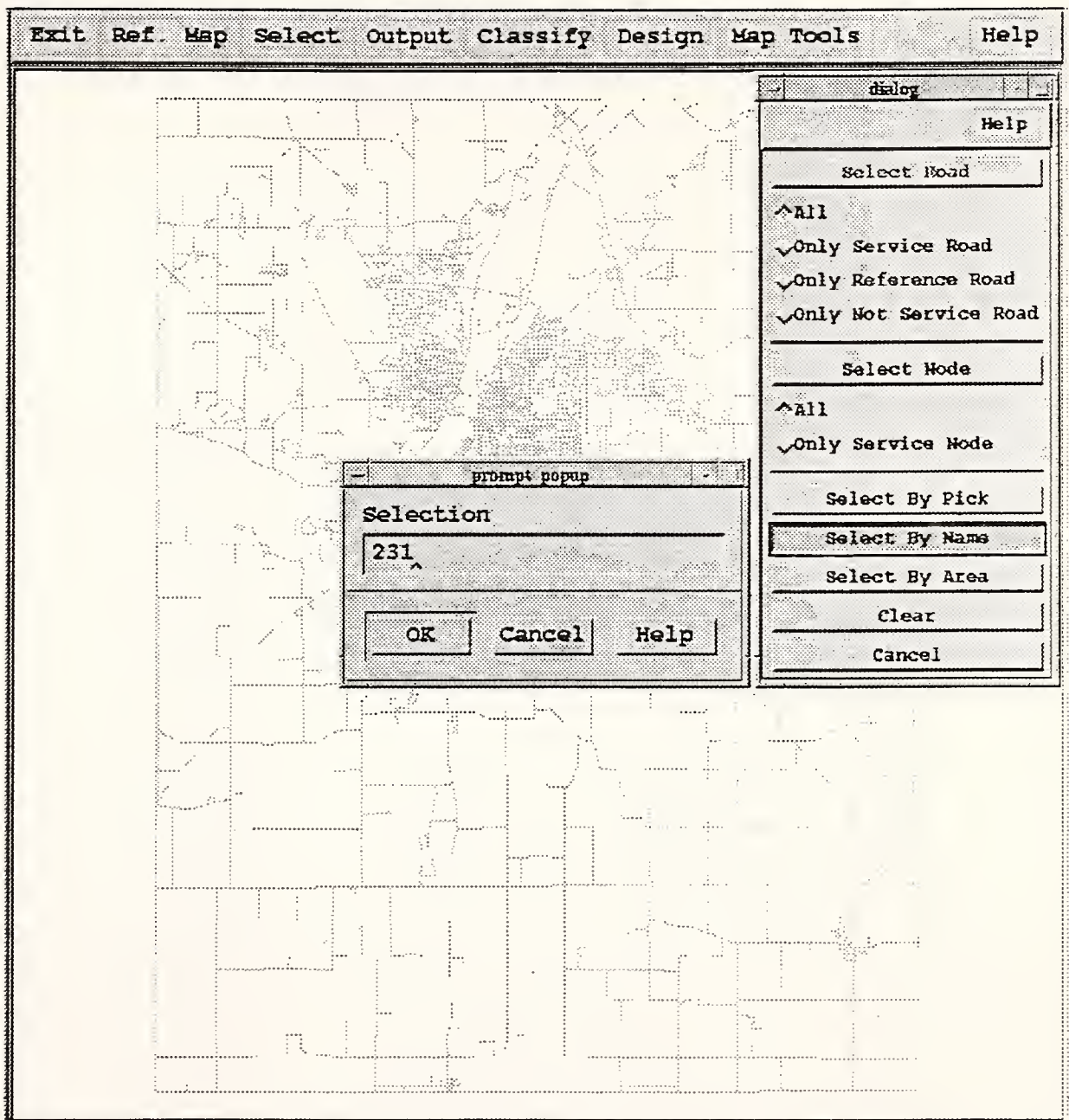
This figure displays the original USGS DLG 1:100,000 data in greater Lafayette area. Dashed lines are used in this example to represent the no-service-required road/nodes. Initially all of the roads and nodes are assumed to be no-service-required. The following figures will demonstrate how to use CASPER to reclassify original USGS DLG data.



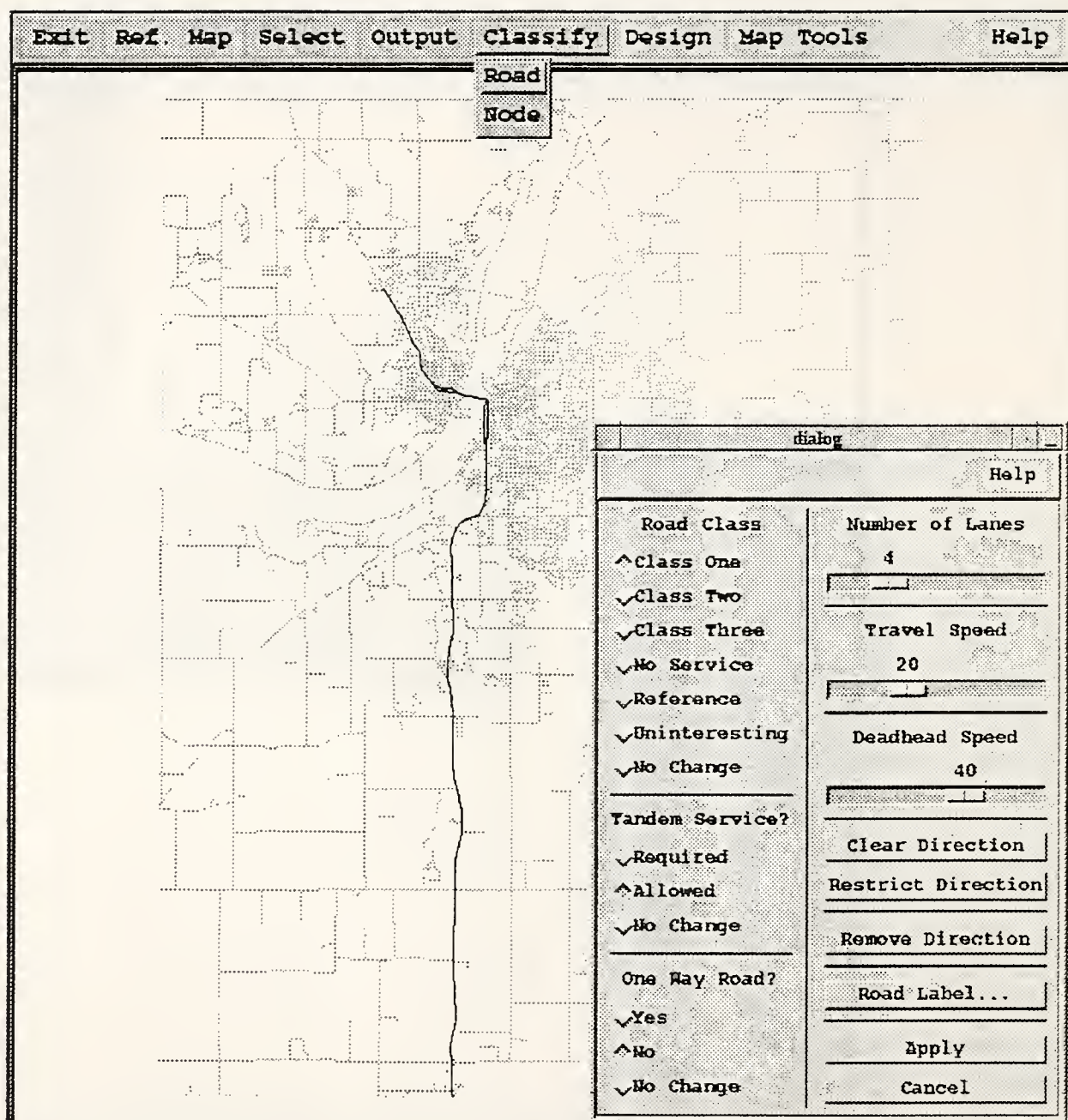
This figure shows how to “zoom” into any portion of a given map. By clicking mouse button on “Map Tools” from the top menu bar and selecting “Zoom” from the pull-down menus, the user will have two alternatives, “Zoom By Area” and “Zoom By Factor.” Assume that user selects “Zoom By Area.” A “Zoom/Area” dialogue box will pop up at user’s disposal. A rubber band window is available for the user to specify the area that (s)he wants to enlarge, when the “Zoom” push function on the “Zoom/Area” dialogue box is activated.



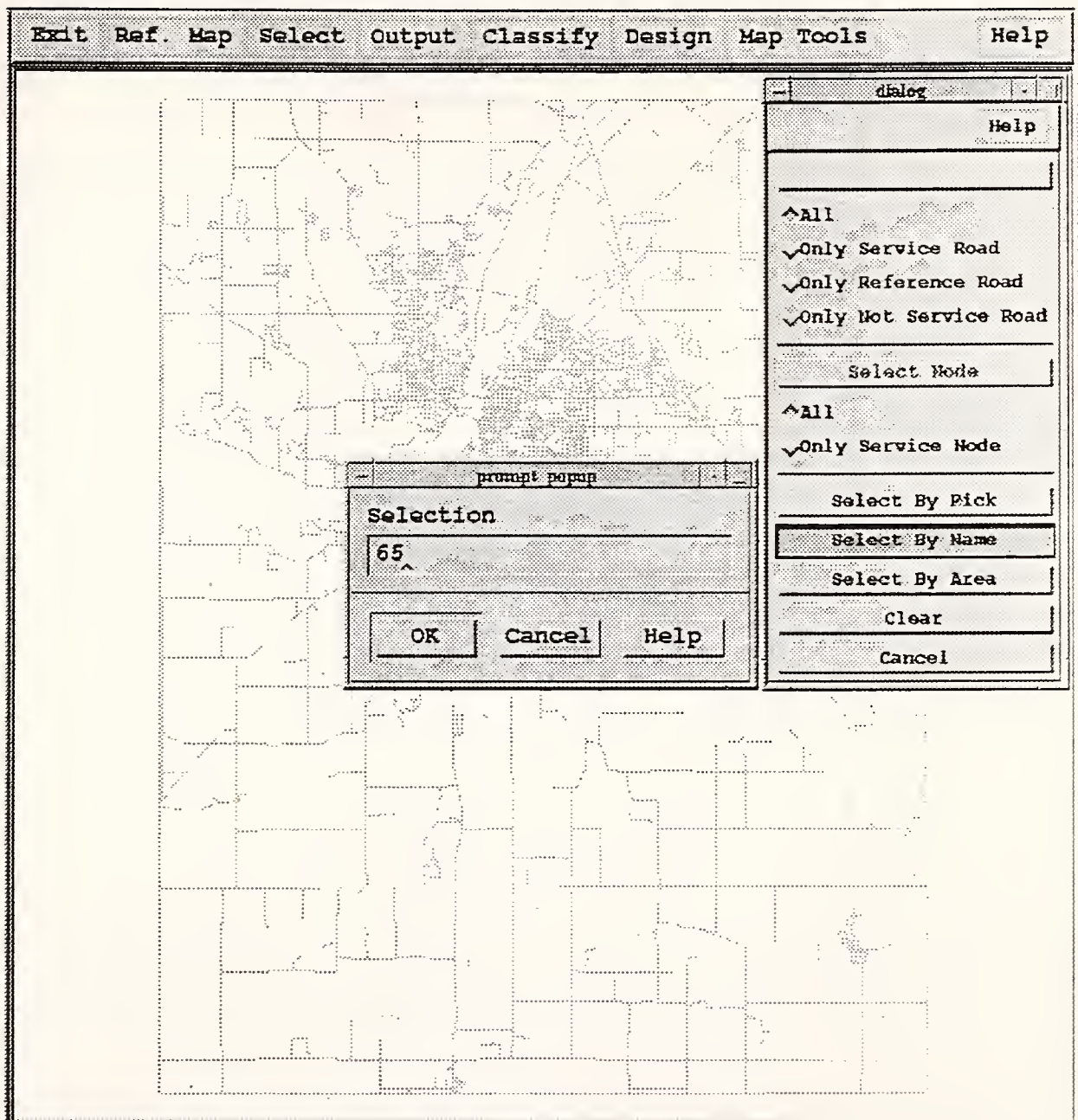
This figure displays the portion of the greater Lafayette area that the user chose to enlarge by using the “zoom by area” function in the previous figure.



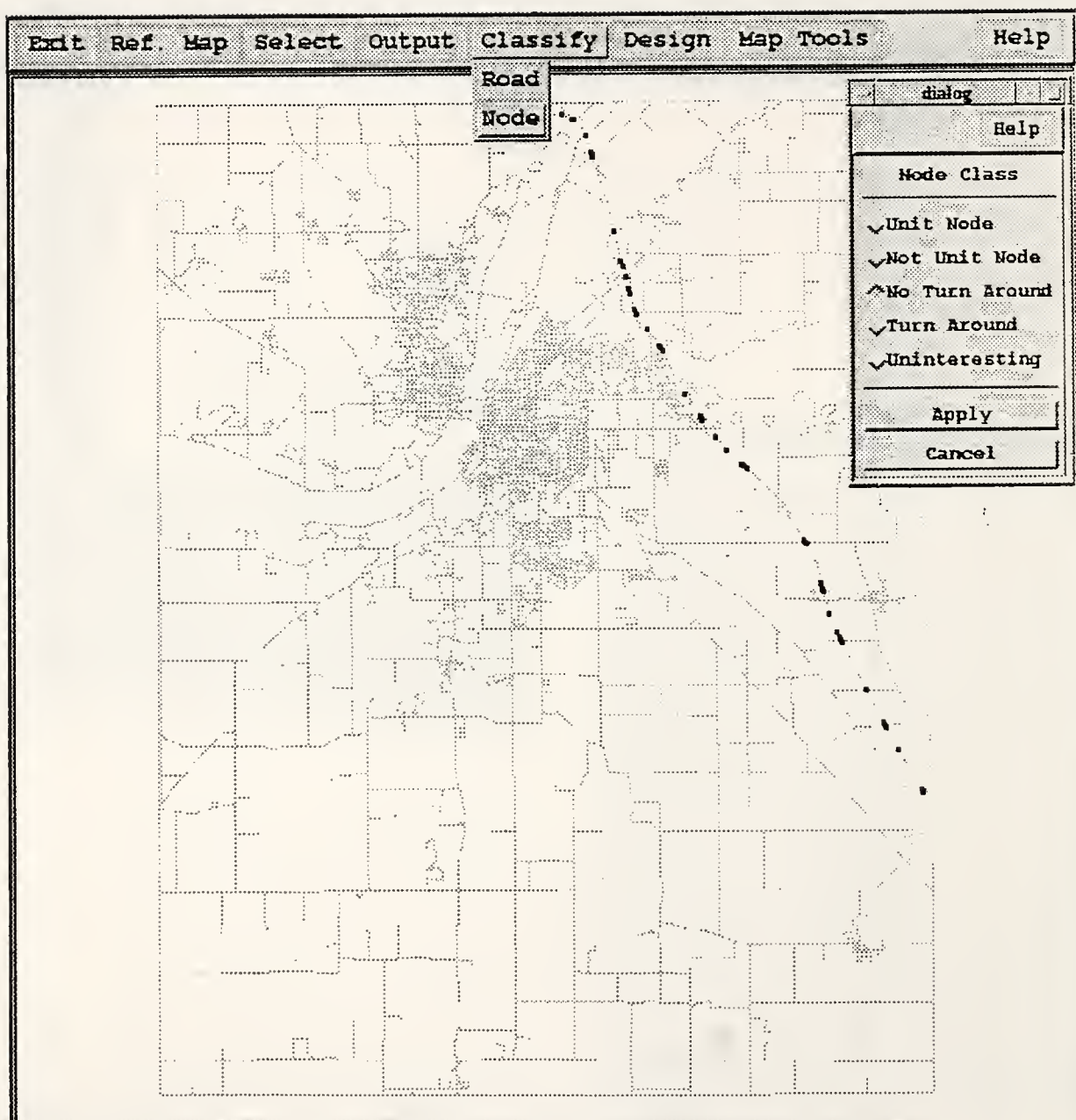
This figure demonstrates how users can select road/node objects. Recall that the original USGS DLG data do not provide enough information for routing purposes, and extra information must be provided by users. Selecting the desirable road/node objects is the first step for this purpose. A "Select" dialogue box will appear when the "Select" function is invoked from the top menu bar. The user has several options to choose from in this dialogue box, such as selecting every road, service road, non-service roads, all nodes, or service nodes. Also, users have three methods of selecting objects: select by pick, select by name, and select by area. In this example, "Select By Name" is activated and number "231" is entered in the associated popup dialogue box. This indicates that the user wants to select every road segment on Highway 231.



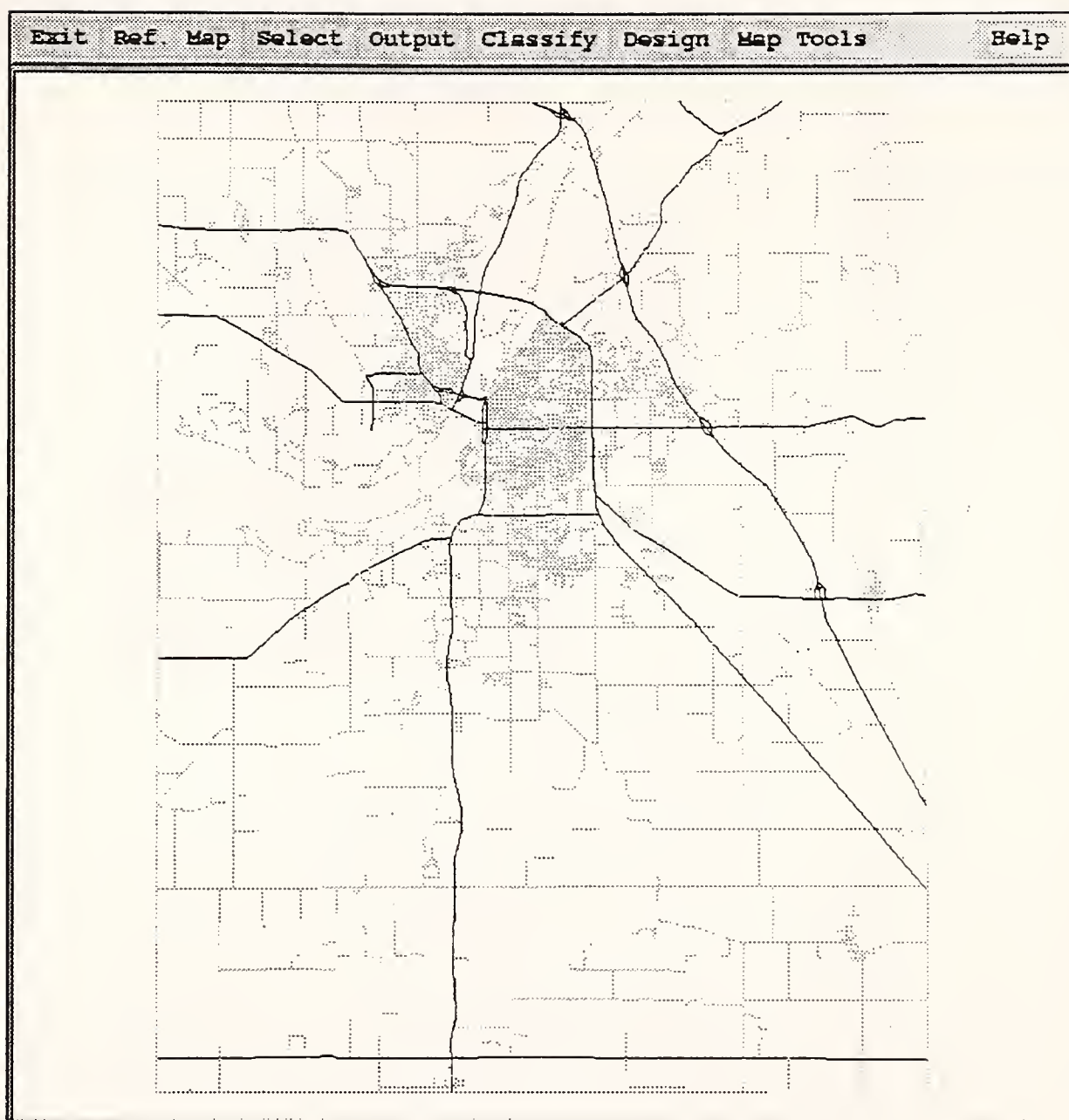
This figure demonstrates the outcome from the previous selection and how users can classify these selected road objects. The solid lines represent the selected Highway 231. By configuring the "Classify Road" dialogue box in an appropriate way and activating the "Apply" button, the attribute codes of the selected road objects will be modified according to the specifications shown on this dialogue box. In this example, Highway 231 is classified as 4-lane class one road. The vehicle travel speeds are 20 and 40 miles per hour while servicing and deadheading, respectively.



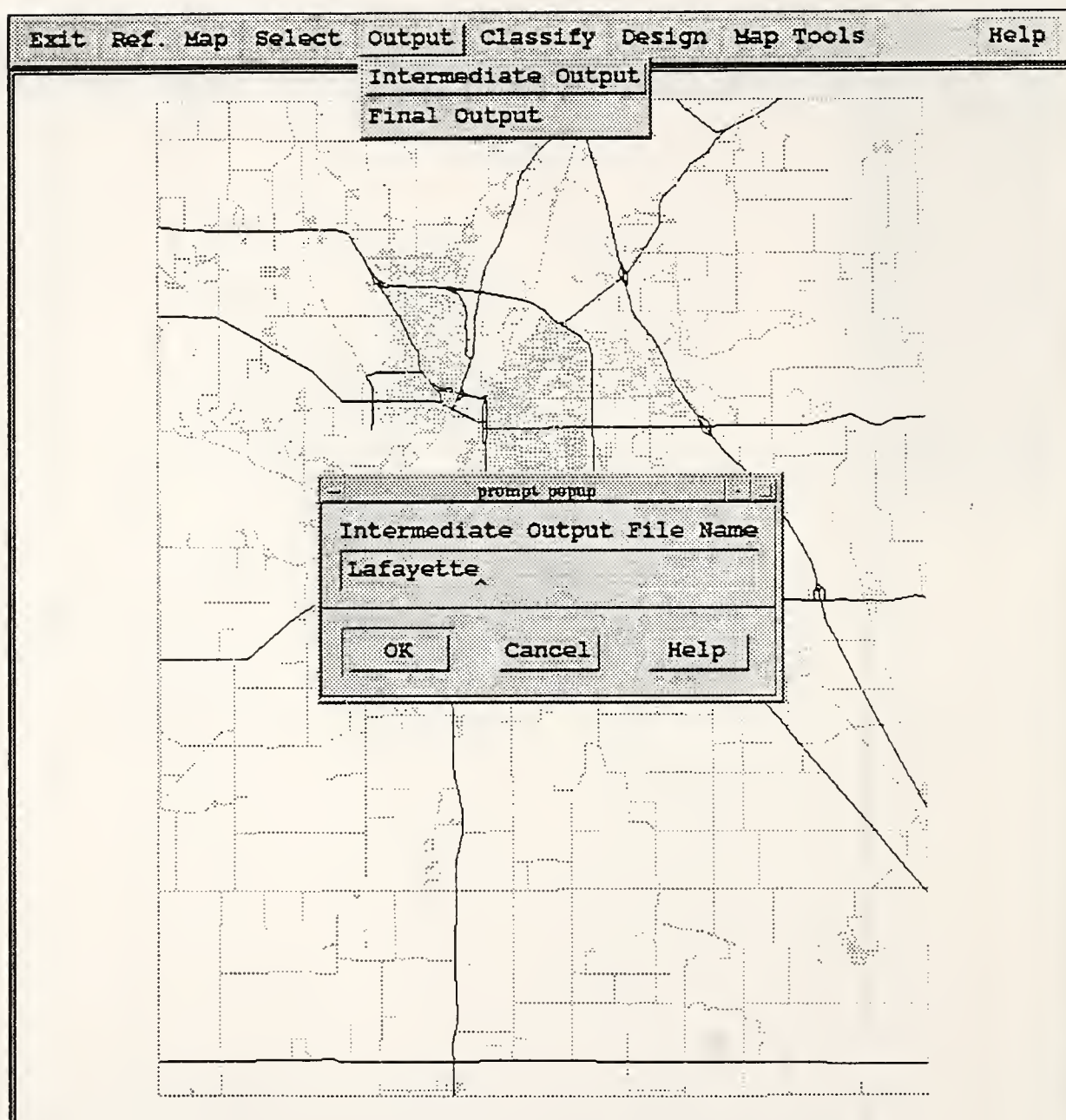
Users may select node objects using procedures similar to selecting road objects. In this figure, the nodes along Interstate 65 are selected using the "Select By Name" method.



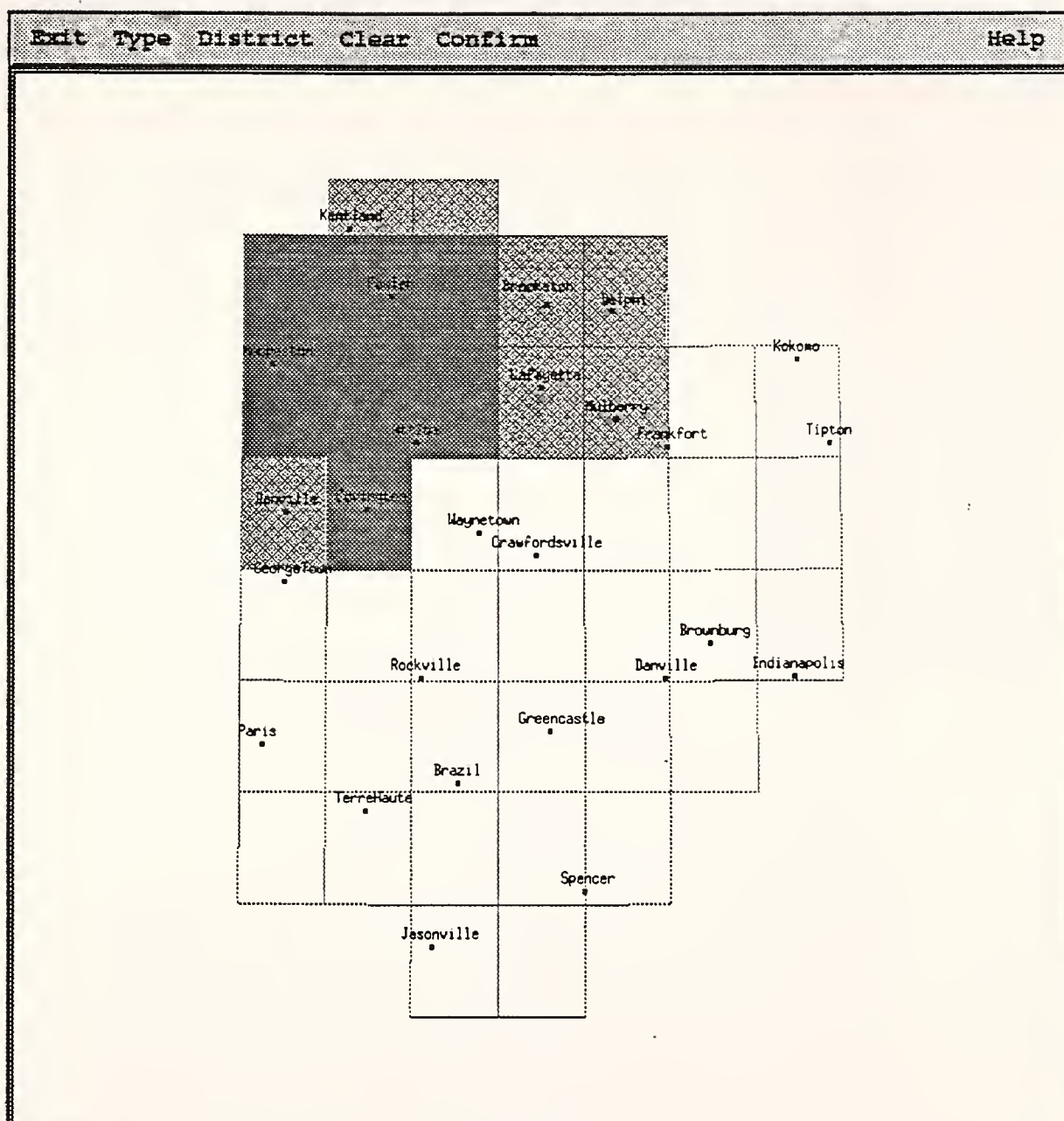
After selecting desired node objects, users can bring up the "Class Node" dialogue box. Using procedures similar to classifying road objects, users may classify node objects based on features provided in this dialogue box. In this figure, the user declares the nodes along I-65 cannot be used as a turn-around point.



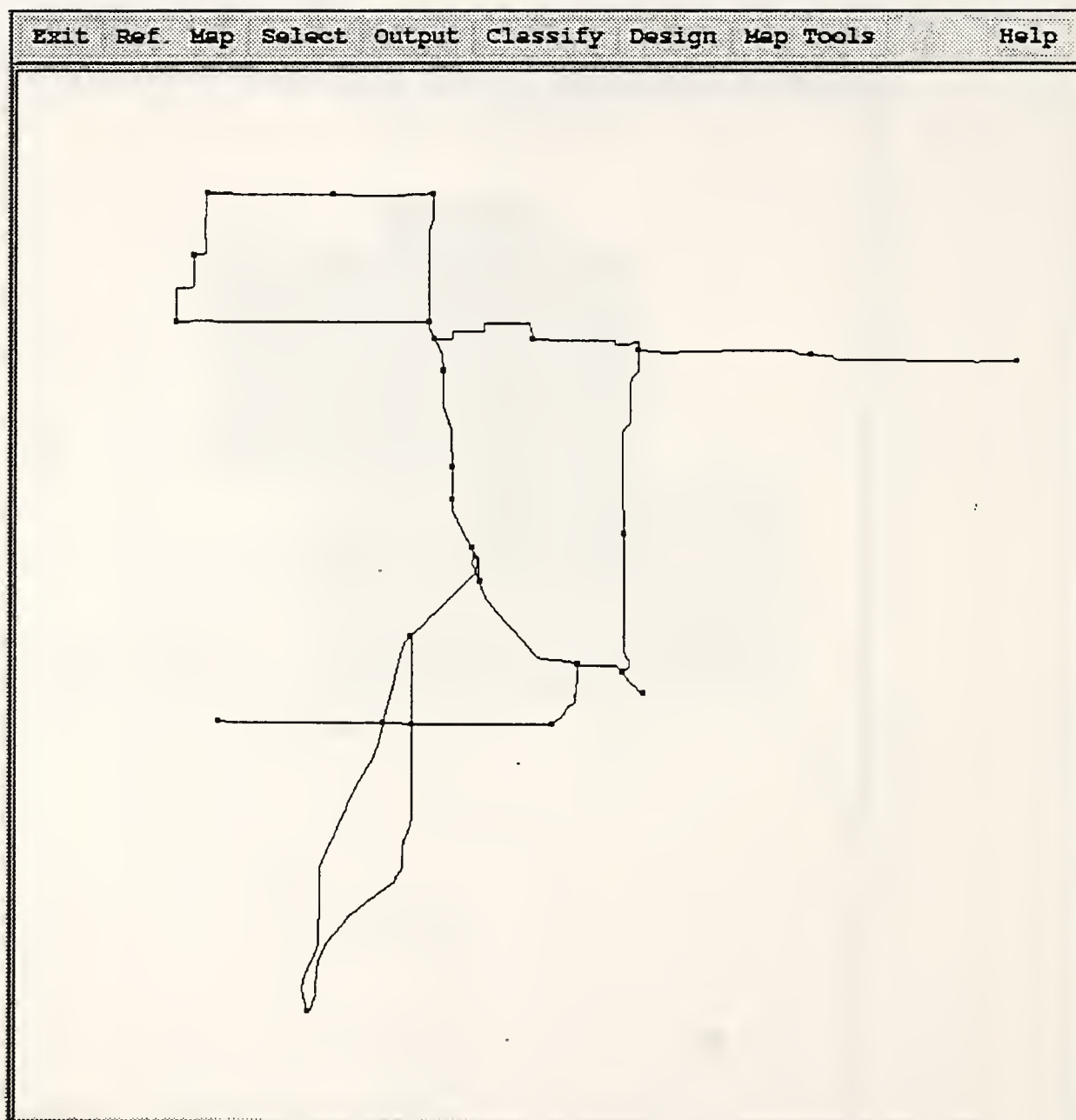
This figures display the greater Lafayette area after all classifications are complete. The solid black lines represent the service-required roads. The dashed lines are the roads that are not maintained by INDOT. The classification of this area was done by Mr. Mike Smith, Gary Bowser, and Bill Smith from the Crawfordsville District.



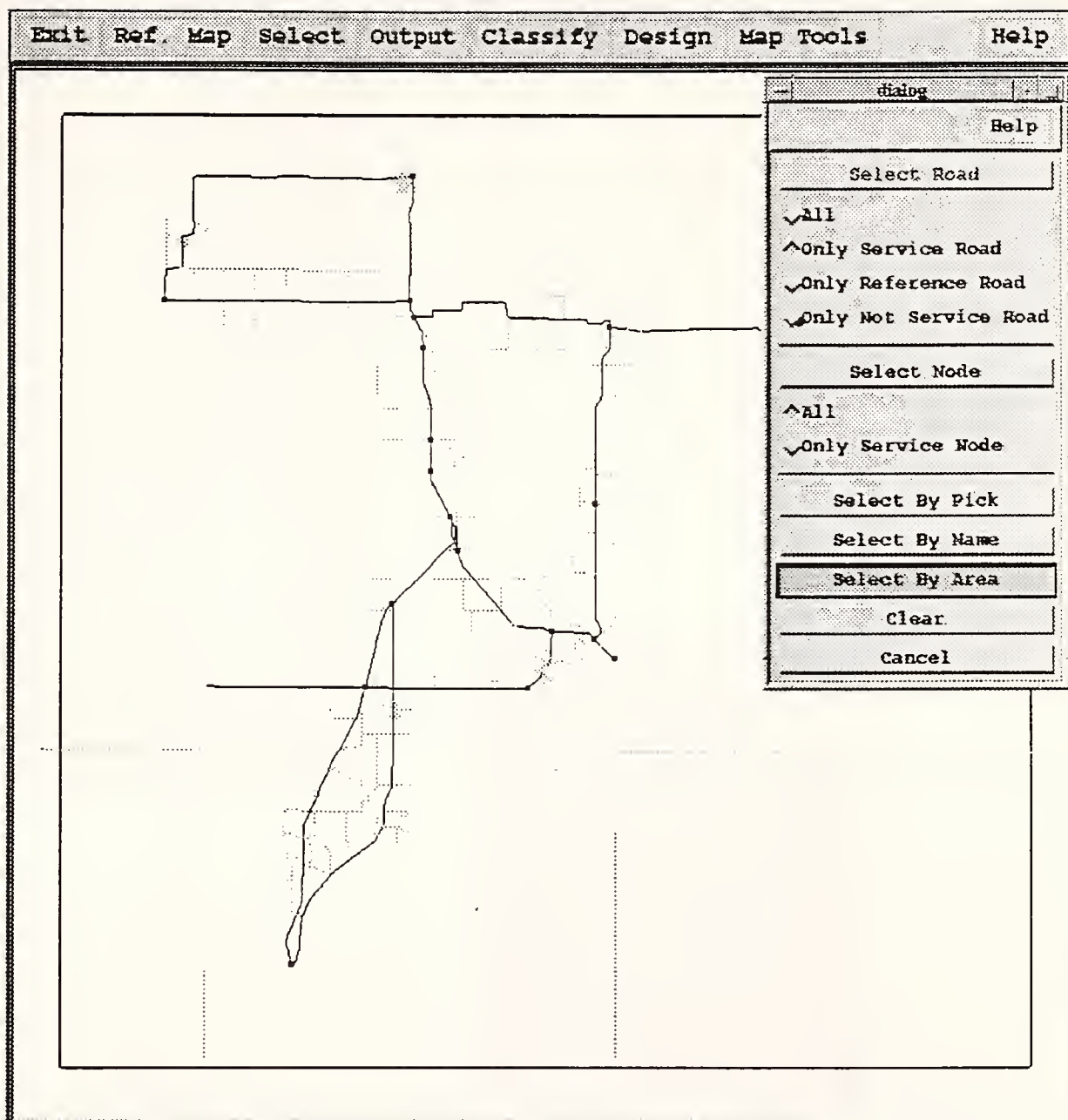
This figure demonstrates how users may save his/her work when data classification is finished. By activating the "Intermediate Output" or "Final Output" function, a dialogue box will appear and solicit an output filename. Users need to enter the output filename and activate the "OK" button to confirm it. The "Intermediate Output" function will save everything shown on the screen. The "Final Output" will only save the road/node objects that require service from INDOT.



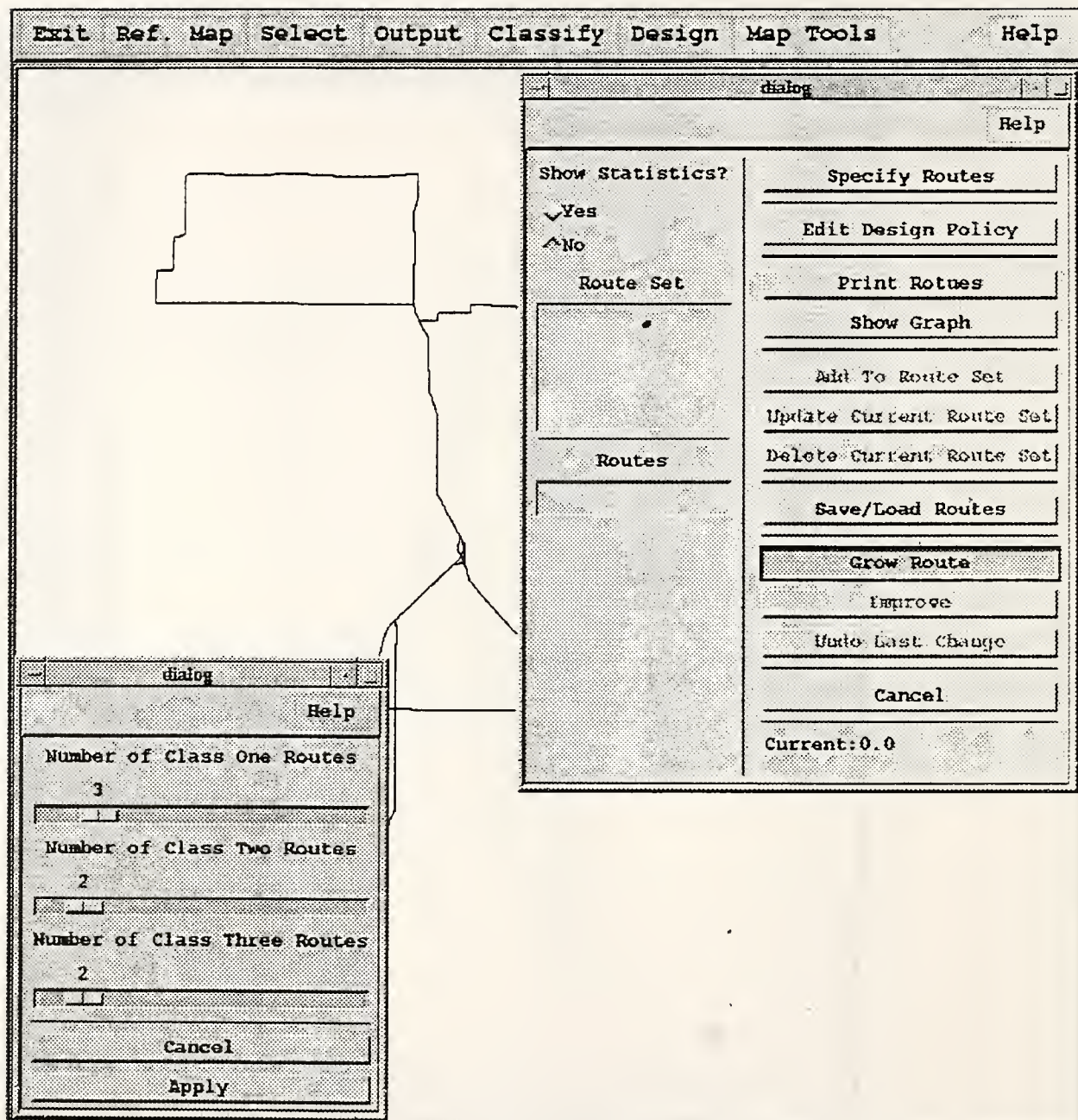
After classifying all of the roads/nodes objects, user may proceed to design routes. The Carbondale unit in Fowler subdistrict (Crawfordsville district), is used as an example here. Usually, a unit area is larger than a single USGS DLG file. Therefore, users need to merge several files in order to obtain an area that covers the desired unit. The darkest area shown here represents the USGS DLG files needed for the Carbondale unit.



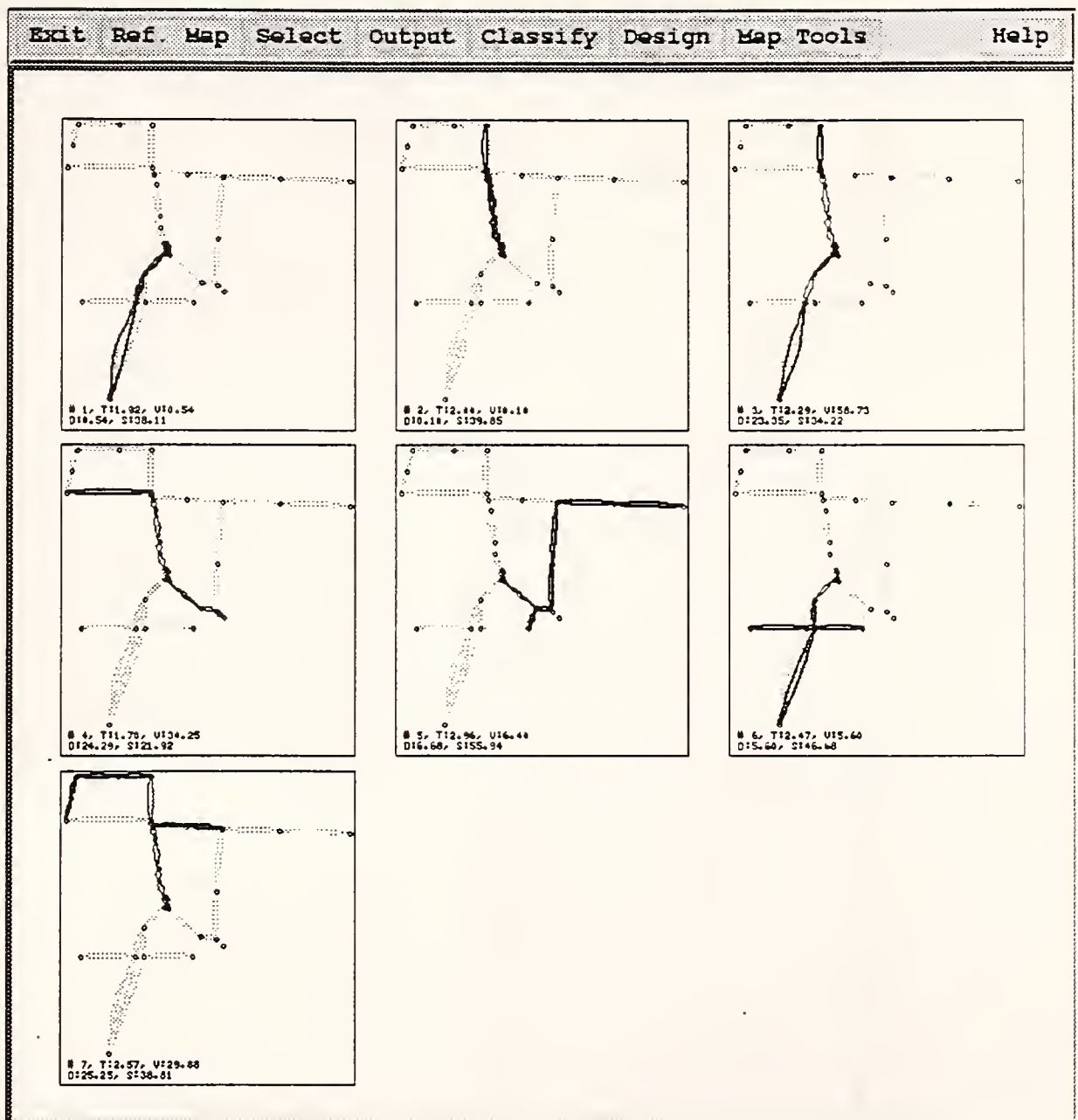
This figure illustrates the area of the Carbondale unit in the Fowler subdistrict (Crawfordsville District). This map is composed from five USGS DLG files. The nodes shown indicate the locations that a turn around maneuver is allowed.



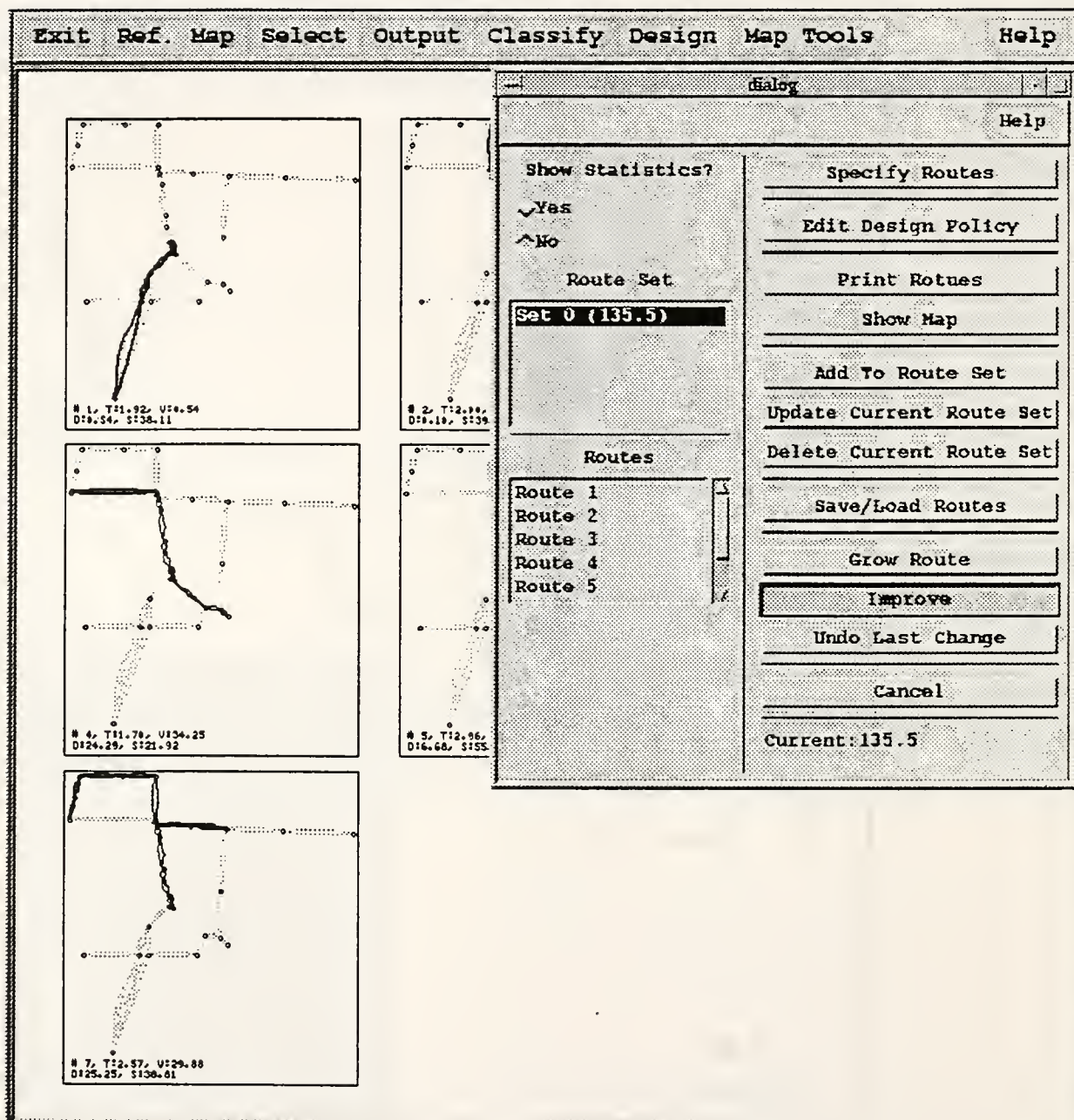
First, users need to specify the area to be routed. In this example, the user will use the selection procedures previously described to select all class 1, class 2, and class 3 roads within this unit.



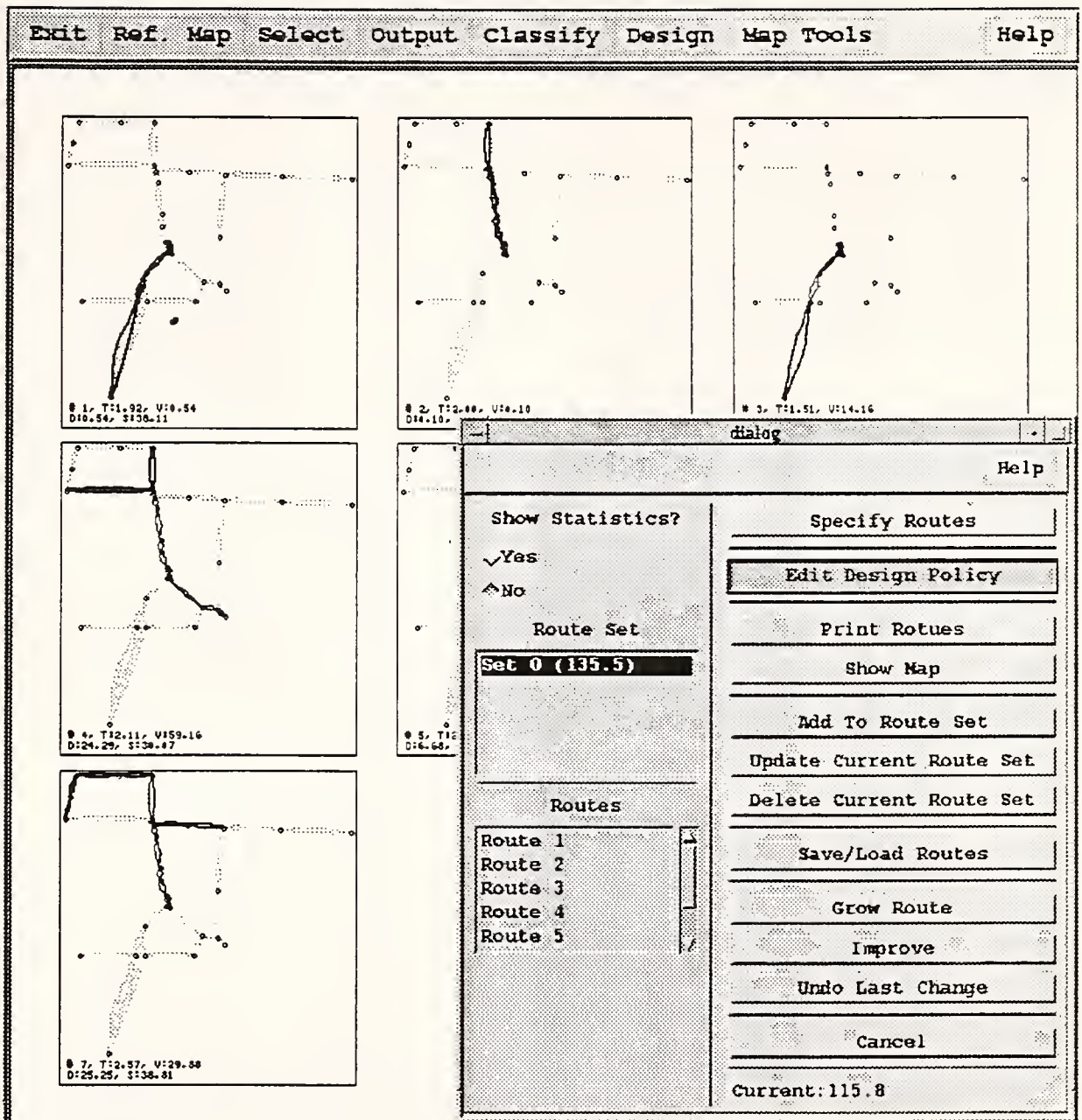
This figure illustrates the “Design” dialogue box that appears when the “Design” push button from the top menu bar is activated. Initially, the user needs to find a starting point (route set) to work with. When the “Grow Route” function is activated, a popup dialogue box will display the suggested number of routes for this area and solicit user’s confirmation. CASPER creates an initial route set based on the values shown in the sliders when the “Apply” button is activated. The rest of the functions on this dialogue box are illustrated in the following figures.



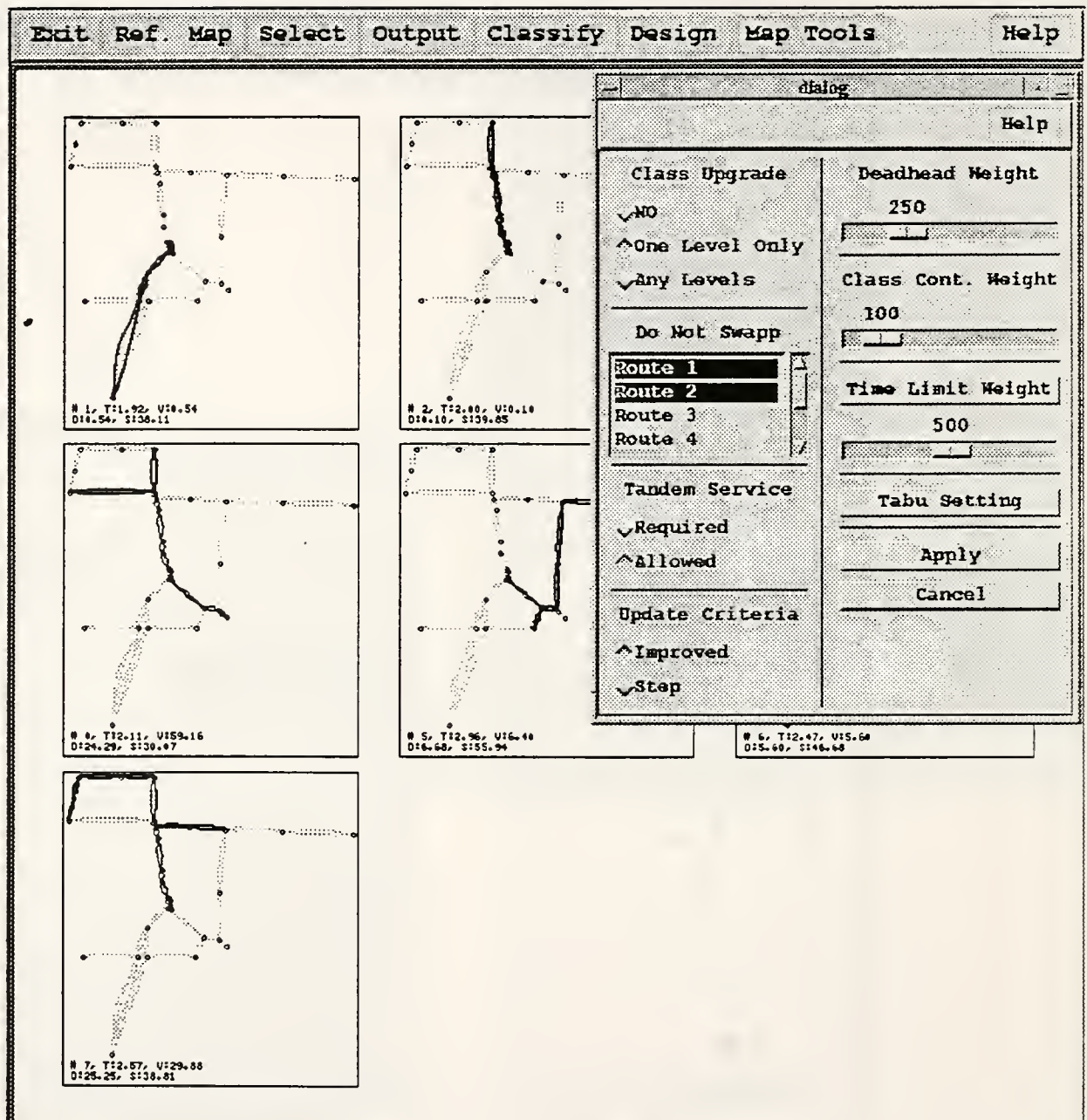
This figure displays the initial route set automatically generated by CASPER. Each rectangular box represents the entire Canbondale area, and a graph representation scheme is used to show route patterns. In this figure, CASPER determines that seven routes is a good number to start with. Route 1 to route 3 are class 1 routes, route 4 to route 5 are class 2 routes, and route 6 to route 7 are class 3 routes. The dashed lines represent the background graph of the entire area. The thick solid lines represent road segments receiving service during the maneuver of any particular route. The thin solid lines represent road segments traveled by trucks without receiving service.



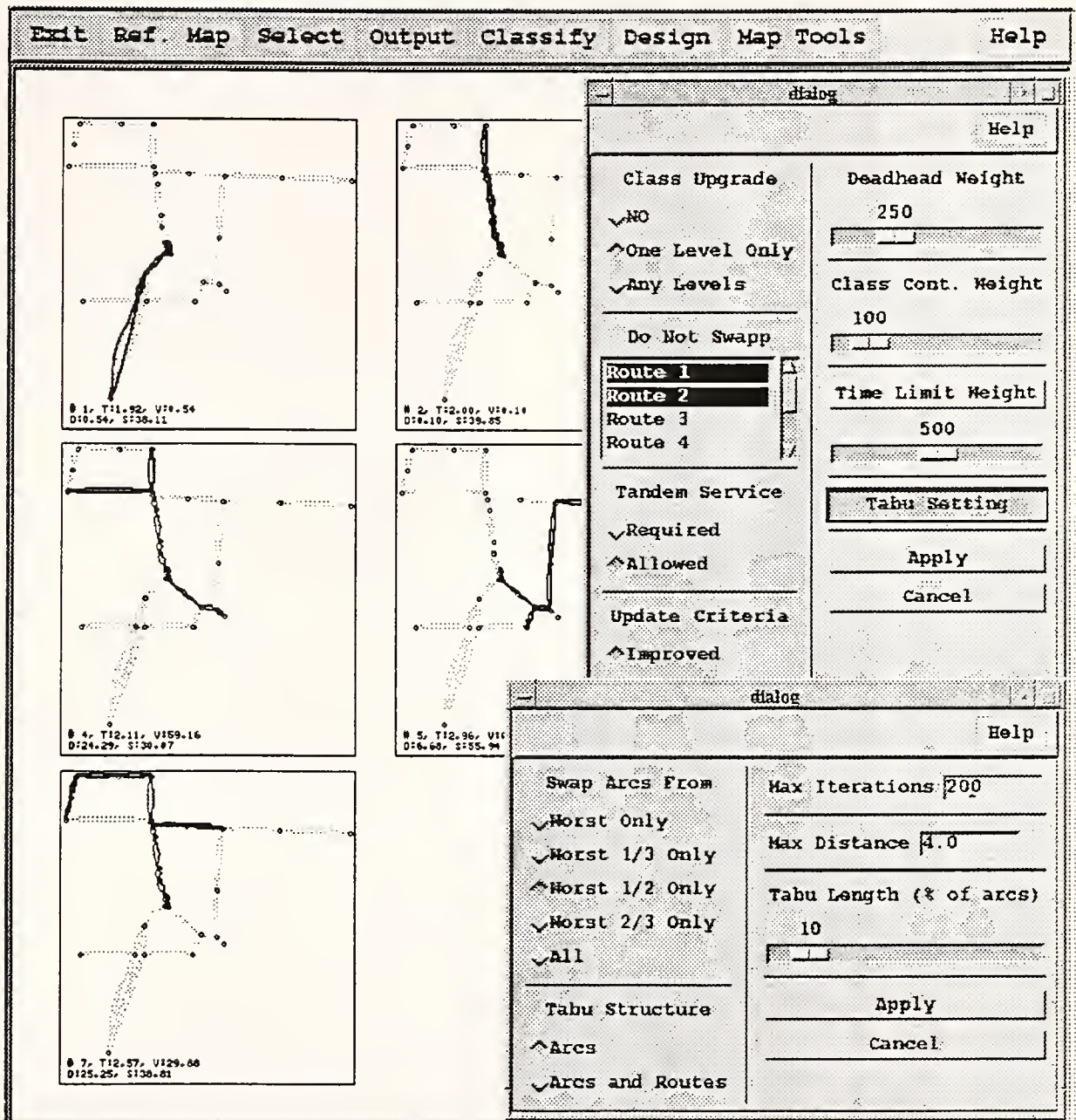
This figure demonstrates how users can save the current working route set to an "inventory" area. In this figure, the user may want to save the current (initial) route set for future use. A route set can be saved to an "inventory" area by activating the "Add To Route Set" button on the design dialogue box. Notice that a new entry of "Set 0 (135.5)" is shown in the "Route Set" list window on the left hand side. The number shown here are "penalty" score of the overall route set. The higher the number the worst the route set is. Entries in the lower list window, "Routes", represent the routes in this particular route set. CASPER cannot guarantee that the initial routes generated are ideal. Users may improve this route set by activating the "Improve" function. The outcome of this improvement is illustrated in the following figures.



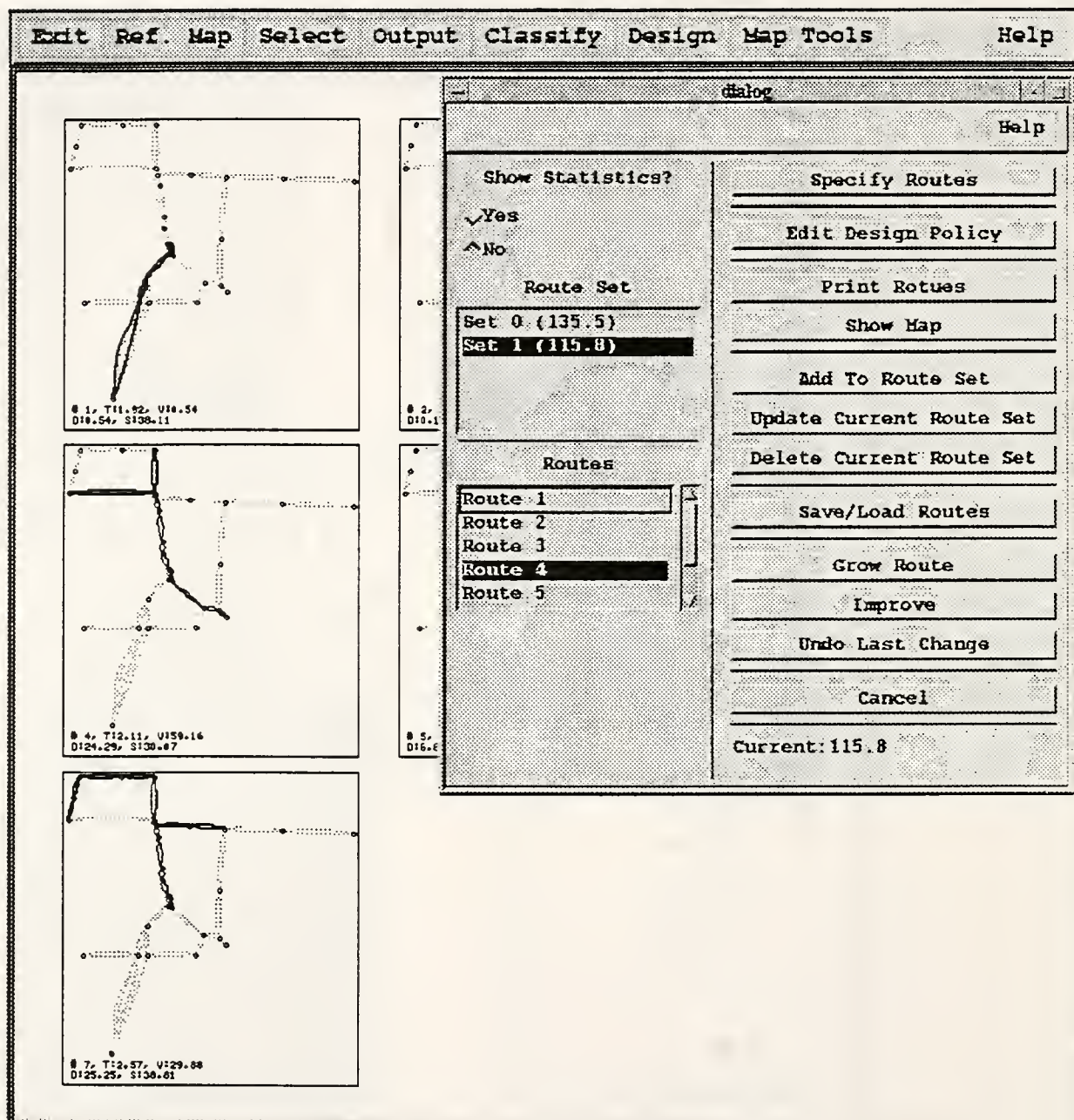
The figure displays the outcome after the first iteration of improvement. Notice that CASPER moves an arc from route 3 to route 4. By doing this, total deadhead distance is reduced but the degree of class continuity violation is increased. In this case, CASPER evaluated this trade-off and determines it is acceptable to sacrifice a bit of class continuity in return for deadhead reduction. In case that users do not agree with this swap, there are two options available. The first one is to activate the "Undo Last Change" to reject this move. The other option is to change the route design policy by activating the "Edit Design Policy" button. The details of how to modify these policies are described in the next figure.



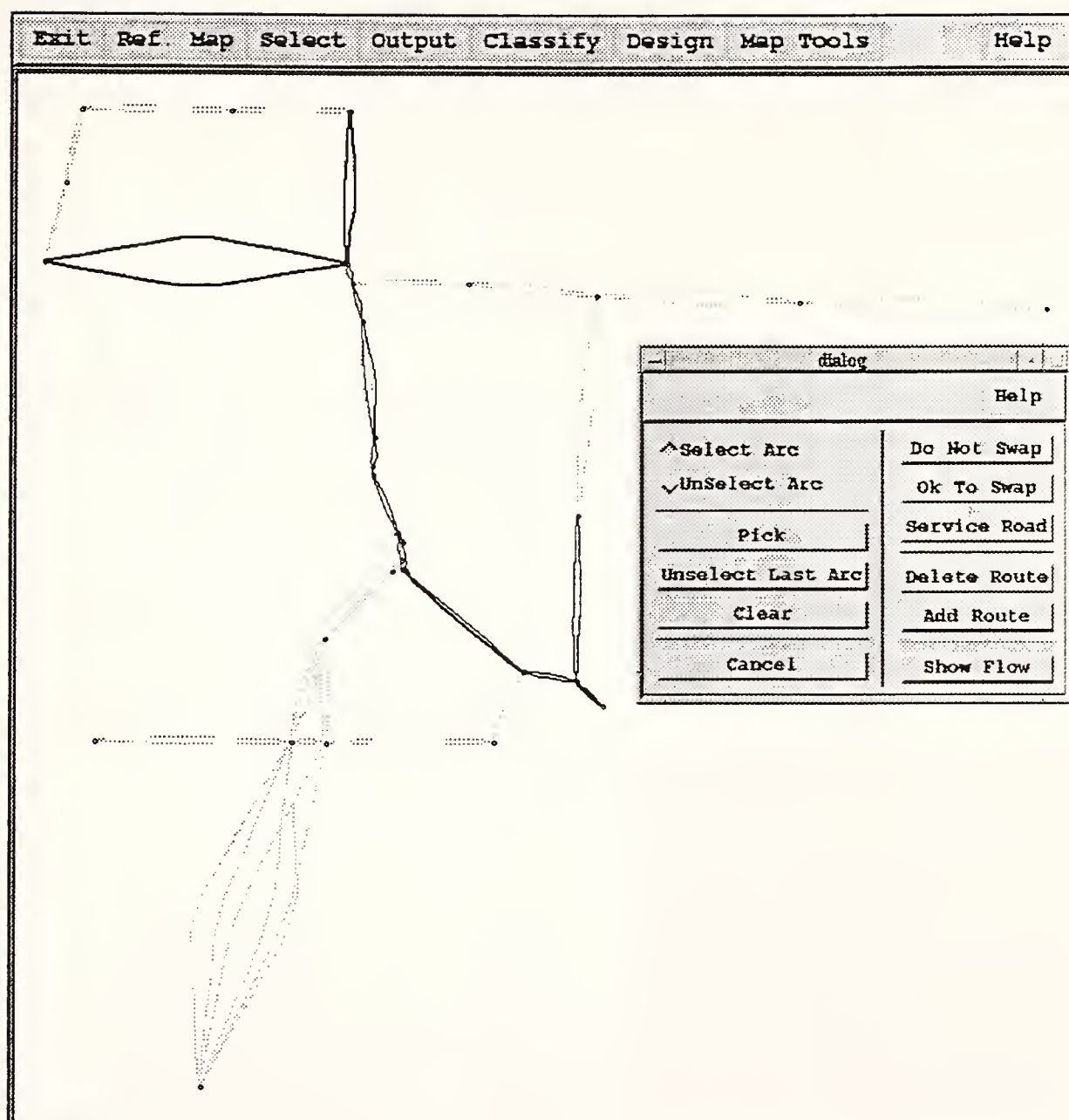
This figure demonstrates how users may instruct CASPER to evaluate the trade-off according to user preference. An "Edit Policy" dialogue will appear when the user activates the "Edit Policy" button on the "Design" dialog. The left hand side of this dialogue box provides the swapping/upgrading criteria, and the right hand side provides the "weights" for each objective. For example, users may move the "slider" associated with each objective to adjust the weight for each objective. In this case, the user determines time limit and service continuity are more important than the other objectives, and route one and two are not allowed to swap arcs with other routes and only one level's upgrade of class is allowed. Notice that users may choose this "Edit Policy" window any time and modify policies in real time.



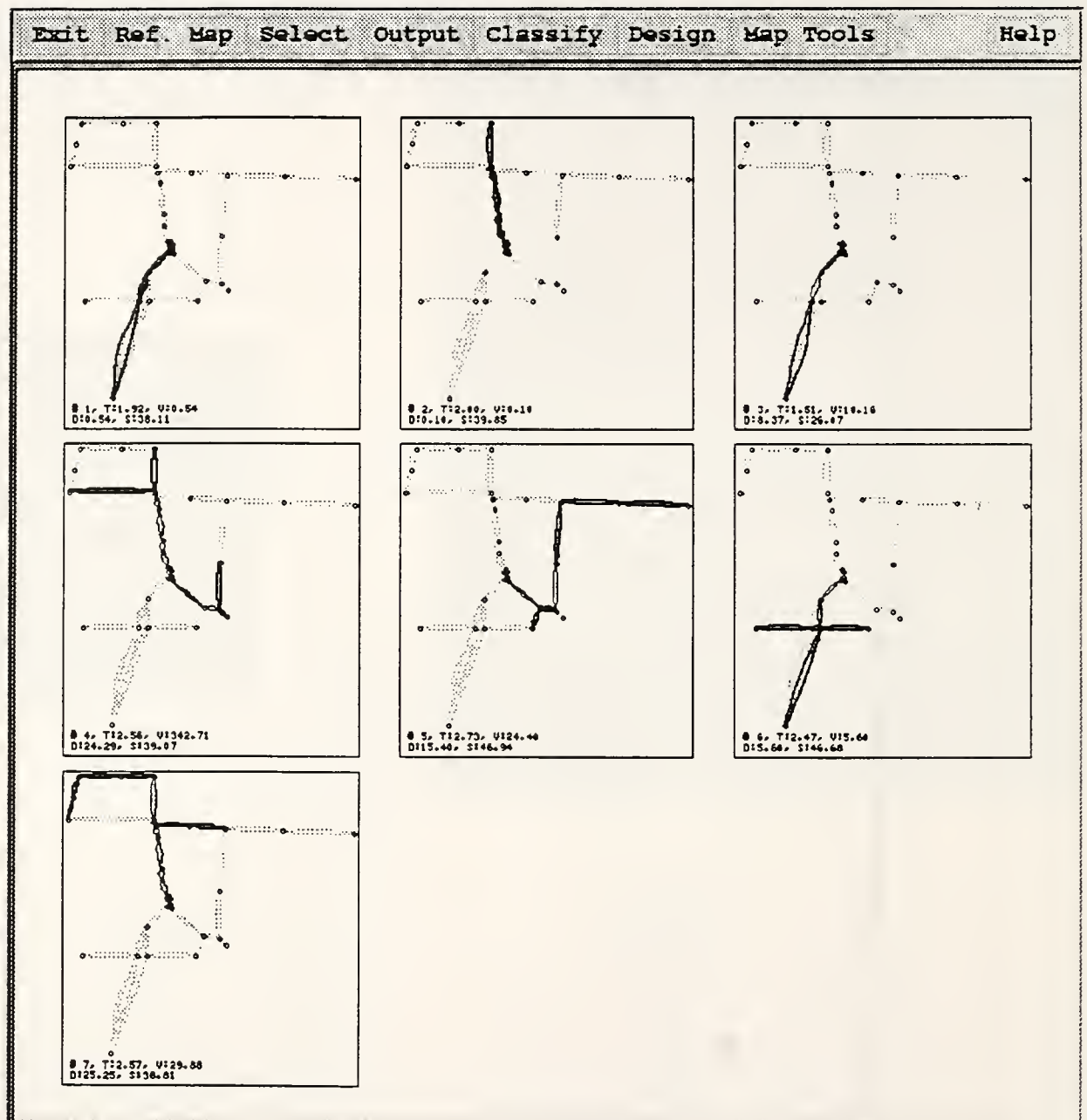
Users are also allow to change the characteristics and behaviors of the Tabu local improvement search as discuss in Chapter 5. In this case, the user determines that only the worst half of arcs will be considered to generate candidates, the maximum number of iteration is 40, the maximum distance allowed for a move is 4 miles and the tabu length is 10% of the number of total arcs.



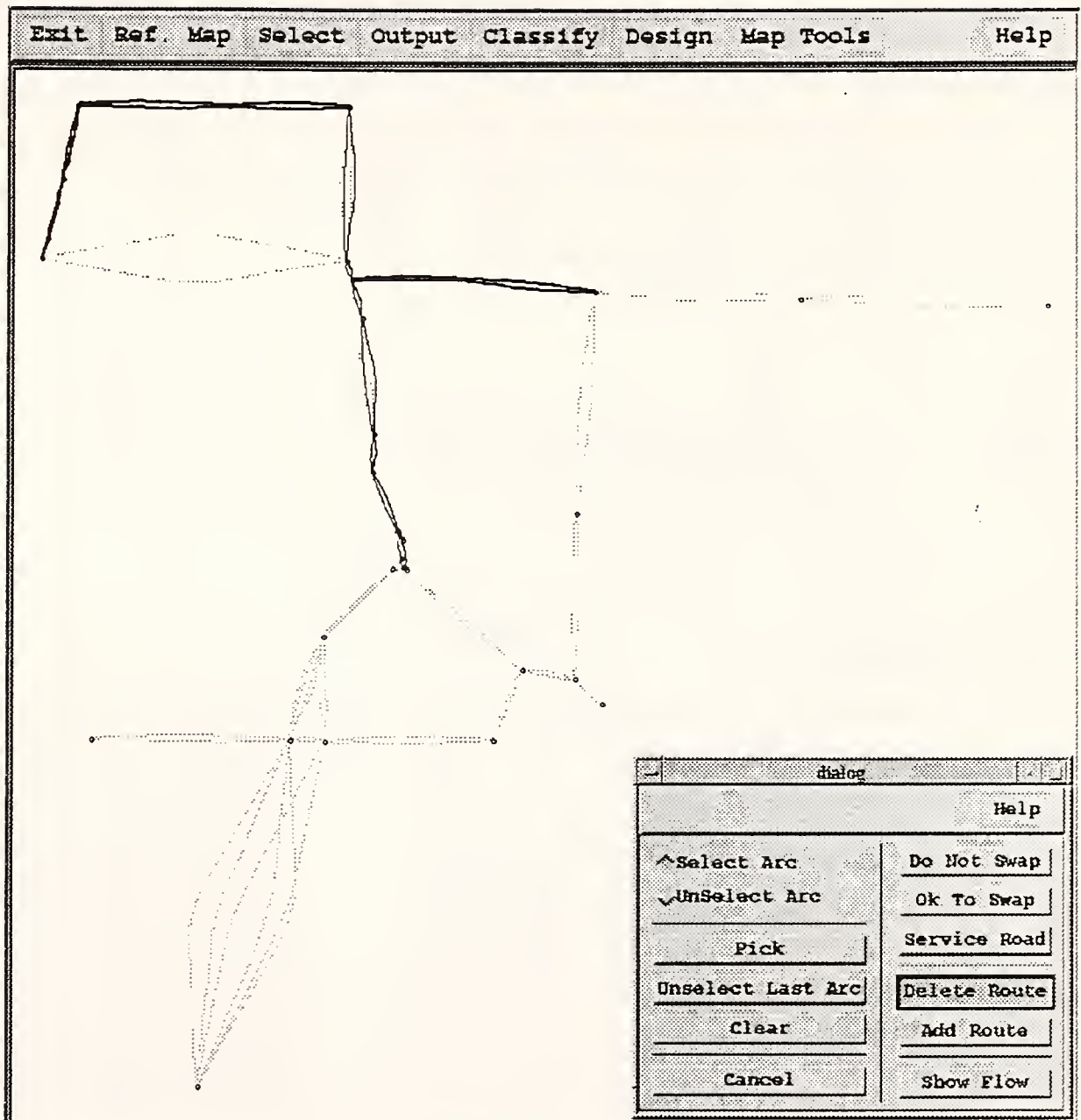
At this point, it may be useful to store the current route set to the "inventory" area again. This figure also shows how to bring any particular route up for a detailed examination. The highlighted bars on the left hand side of the dialogue box indicate the user wants to examine route 4 from route set 1 in details.



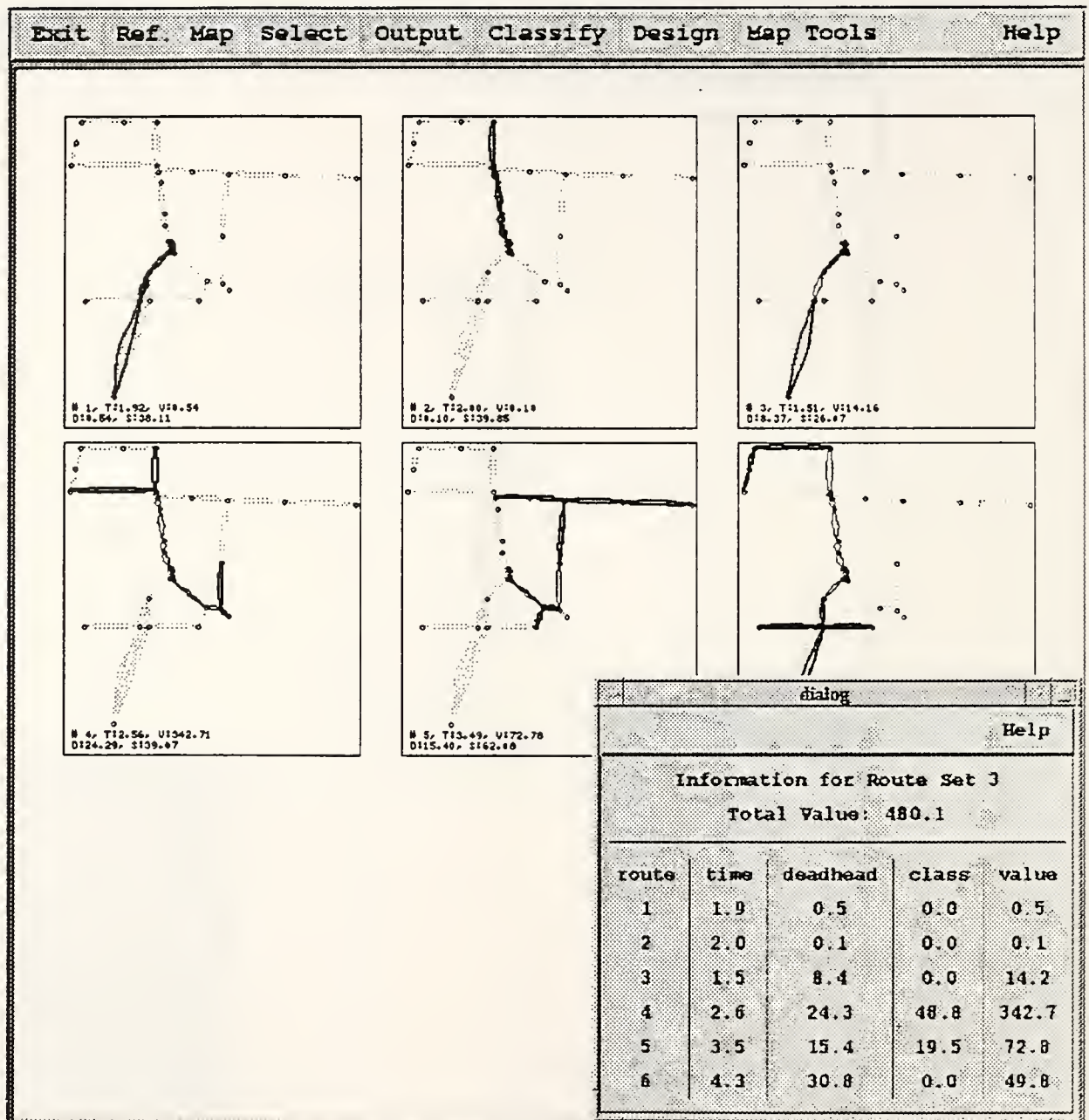
This figure displays route 4 from route set 1, as indicated in the previous figure and demonstrates how users may modify a particular route manually. Using route 4 as an example. Suppose the driver assigned to this route is a 10 year veteran driver and the designer would like him(her) to serve a longer distance in order to reduce the load of rookie drivers. However, CASPER does not have enough information for making this adjustment. By activating the "Edit Route" function, a "Modify Route" dialogue box will appear and allow users to modify the route manually. Users may select road segments to force this route to service/deadhead them, and CASPER may be instructed not to modify them.



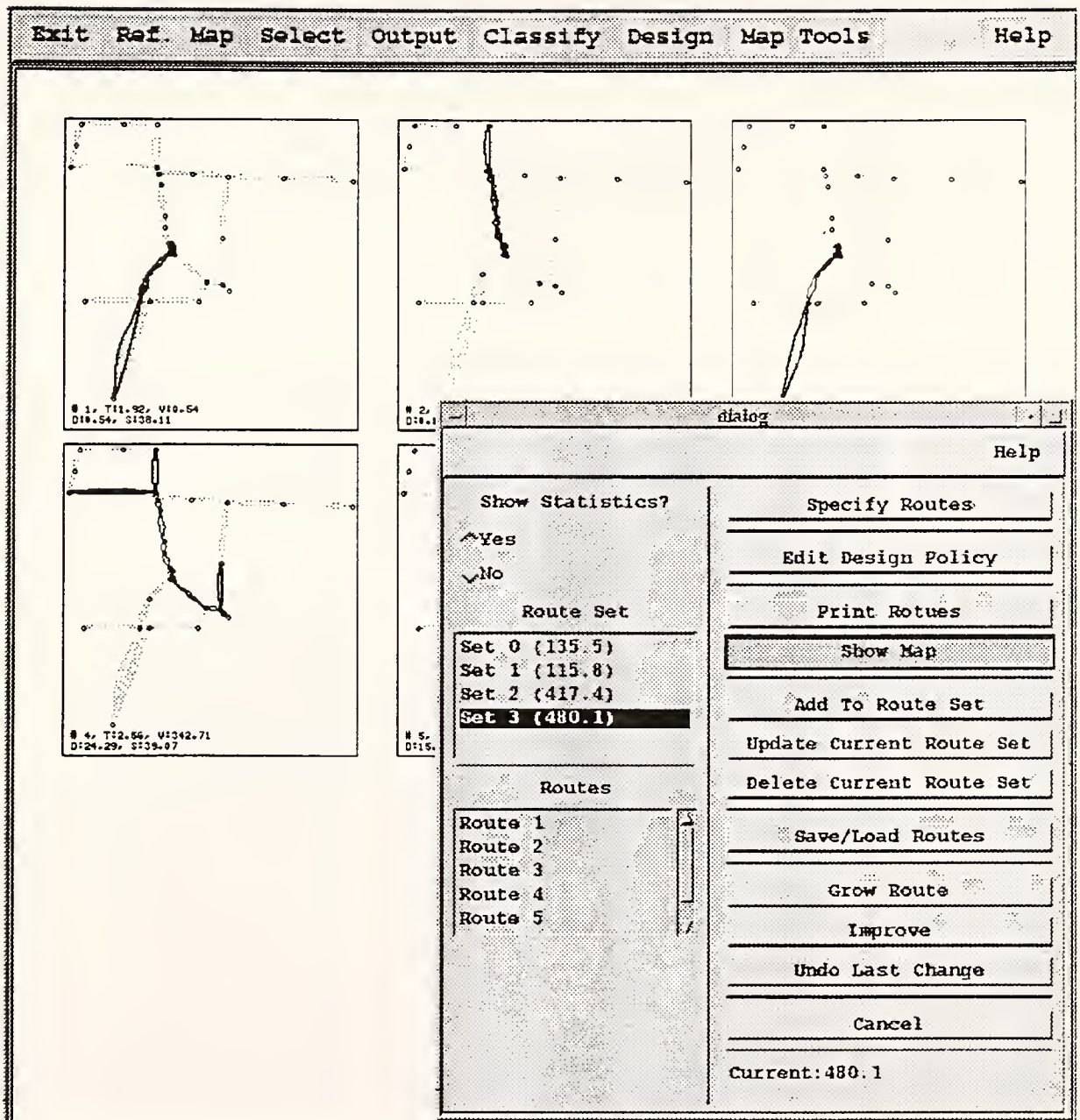
This figure displays the current route set after the user modifies route 4 to accommodate an extra pair of road segments. According to this configuration, some of the routes are not very good. Users have several alternatives here: to keep asking CASPER to improve routes, to modify policy setting, to step in and modify routes manually, or try to eliminate one of these "bad" routes. In the following figure, the mechanism of how to eliminate one route will be demonstrated.



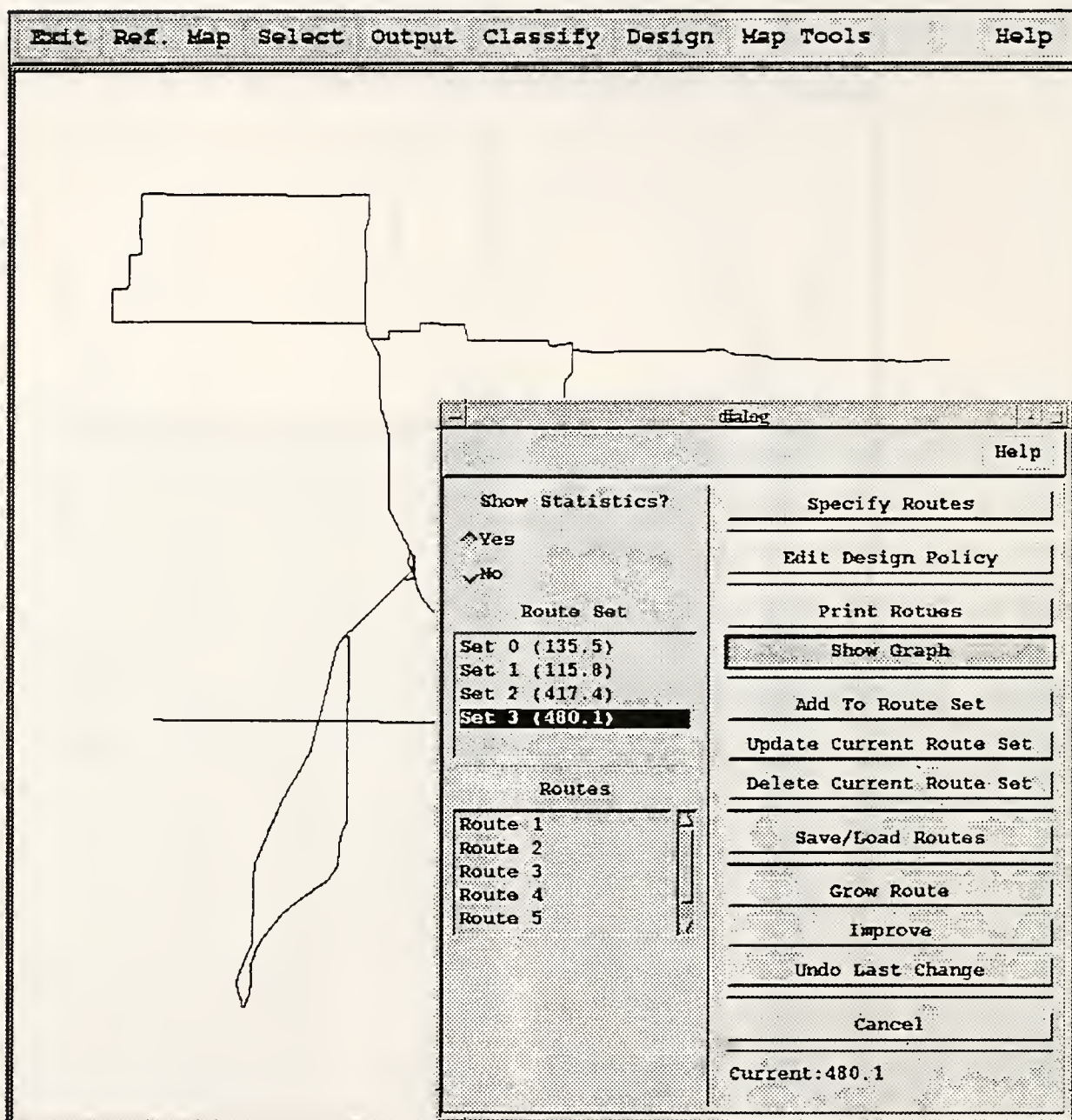
This figure demonstrates how users may delete a route manually. By following procedures mentioned previously, users may bring up route 7 (the route that will be eliminated) as well as the "Modify Route" dialogue box. The current route can be deleted by activating the "Delete Route" function.



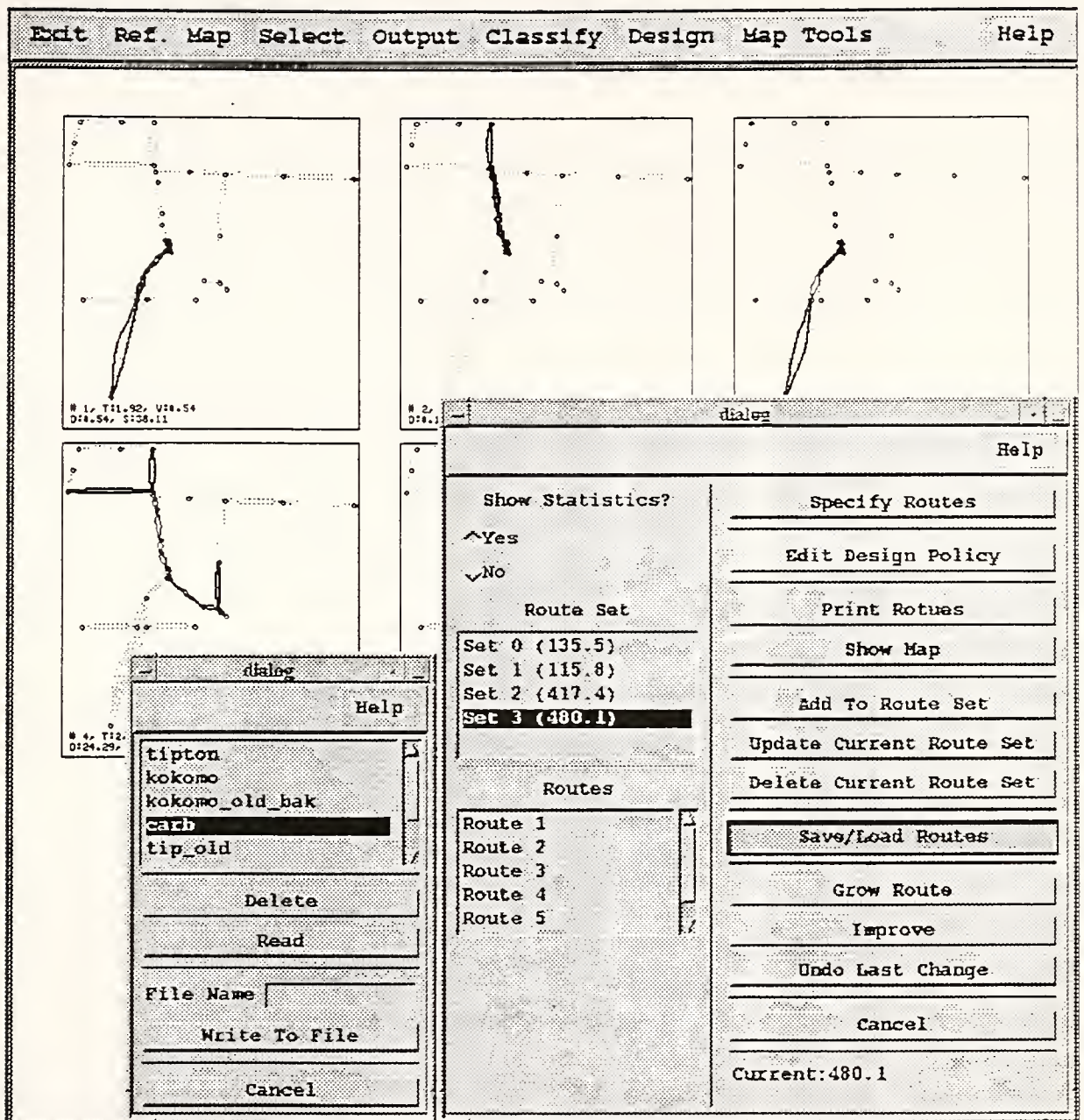
This figure illustrates how the current route set will look after route 6 has been deleted. CASPER will assign road segments from the deleted route to other routes. As indicated in the information window, the total penalty score jumps to 480.1. This increment is somewhat expected because total amount of resources (trucks) has been reduced. The "Improve" function as well as the other mechanisms discussed previously can be used to improve this route set. Also, a dialogue box which contains the statistics of these routes can be popped up upon user's request. This dialogue can show the "penalty" score of each individual routes that are partitioned into different objectives.



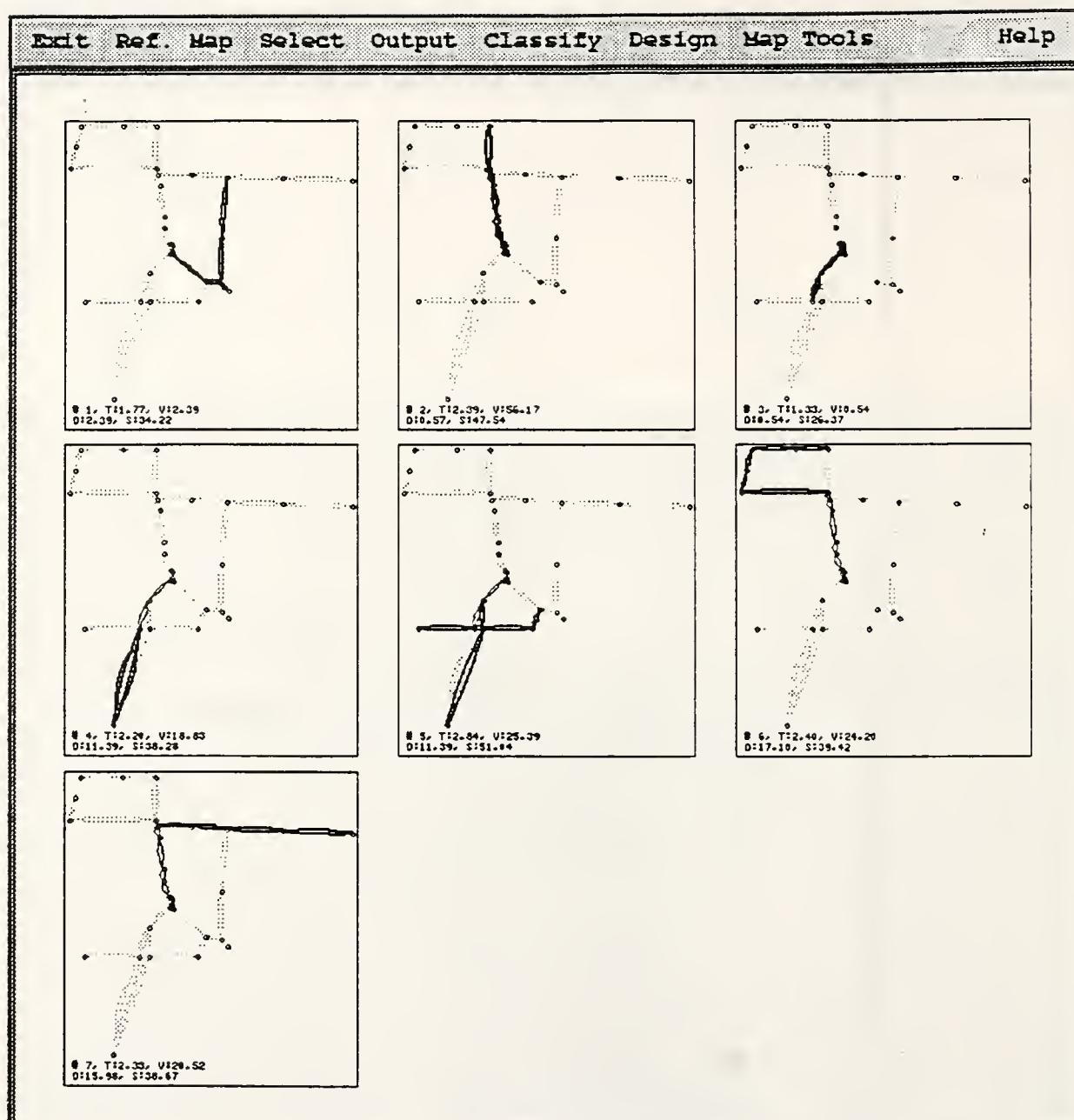
It may be desirable for the user to return to the map representation scheme and change some attributes of roads/nodes in order to obtain more flexibility. This figure demonstrates that users may return to the map representation by activating the "Show Map" button on the design dialogue box.



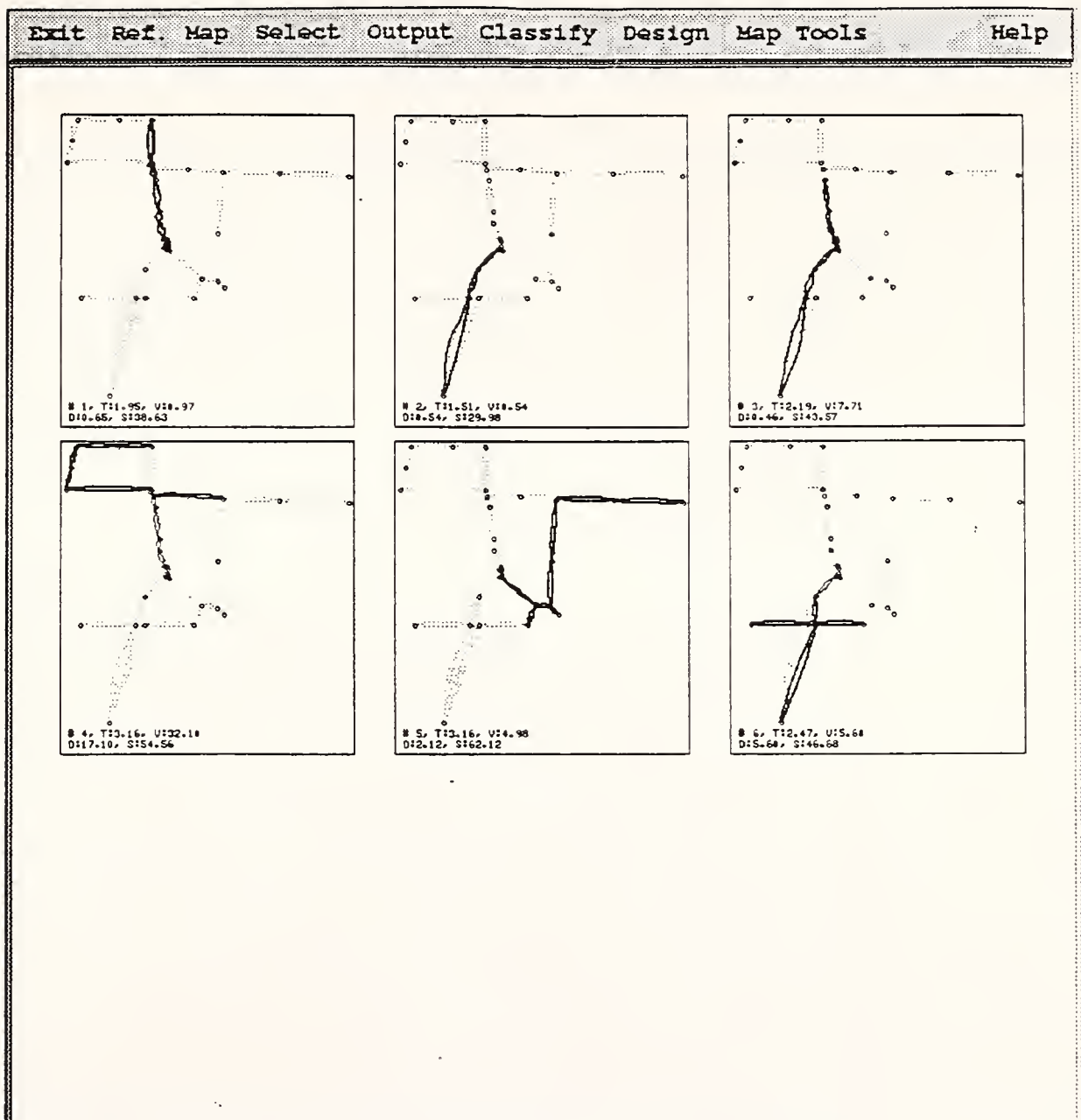
This figure displays the DLG map of the Carbondale unit when the user changes from graph (route) representation to map representation. Users may change classifications of roads and nodes, and these changes will be mapped to the associated arcs/nodes in graph representation. By activating the "Show Graph" button, users may go back to the graph (route) representation again.



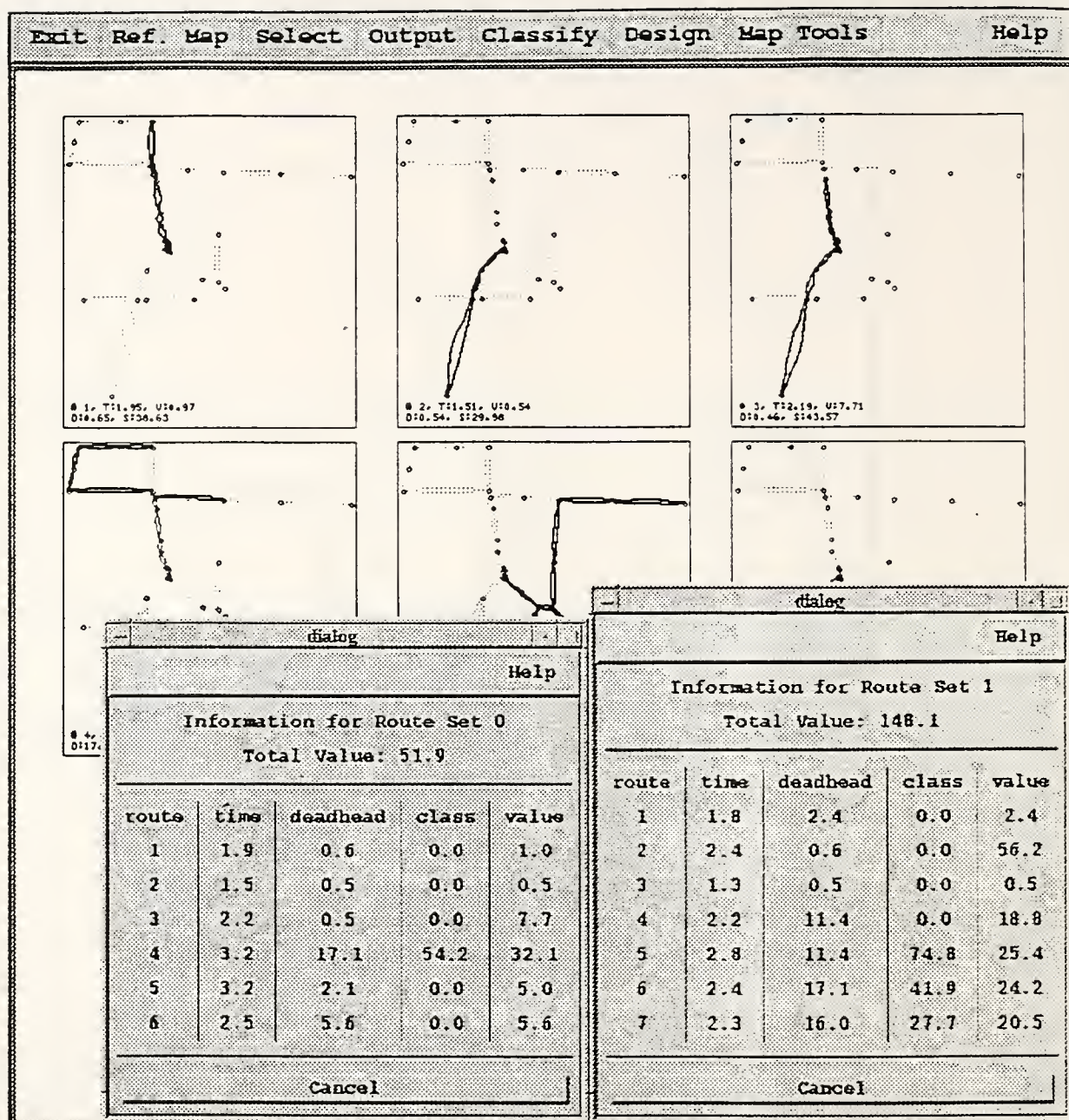
This figure demonstrates how users could save the current work into a file and retrieve it later. A dialogue box will appear when the "Save/Load Routes" function is activated. Users may enter the name of the file used to store current work into the "File Name" area. Or, a name can be selected from the scroll list area and the information stored in this selected file will be retrieved. In this example, file "carb" is selected from the scroll list. When the "Read" function is activated, the information stored in file "carb" will be retrieved and displayed on the screen. The carb file contains the existing routes for the Carbondale unit and the routes designed by using CASPER. The configurations of these two sets of routes are displayed in the following figures.



This figure displays the current routes used in the Carbondale unit. There are seven routes used.



his figure displays the routes designed by using CASPER. These six routes were designed by Mr. Mike Smith from the Crawfordsville District.



This figure displays the comparison between current routes and the routes designed by Mr. Smith. With the help of CASPER, Mr. Smith only needs 6 trucks to serve the entire Carbondale unit, while at the same time providing a better level of service.

COVER DESIGN BY ALDO GIORGINI